TDS Workshop User Guide

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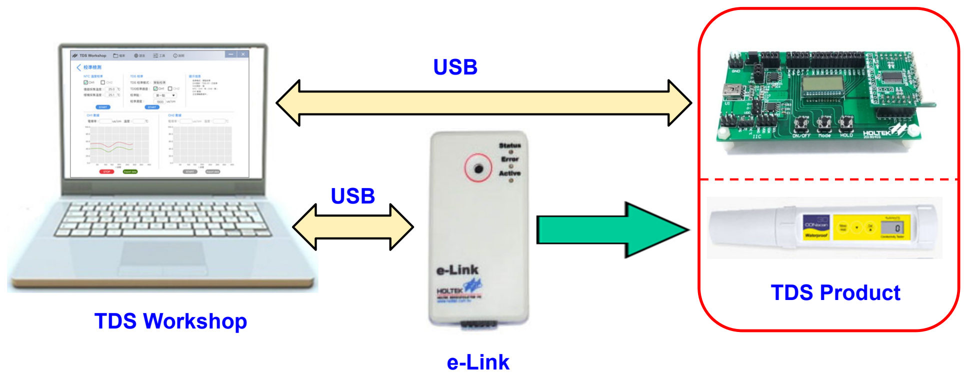
1 Development Environment

The Holtek TDS Workshop is a software development platform for TDS application development. This platform integrates TDS measurement, temperature measurement, key inputs, display, communication and other functions, providing users with a means of rapid functional configuration and object code generation. A calibration monitoring window is also provided to facilitate calibration and real-time data monitoring. The graphical operation interface allows for easy and convenient user development thus greatly reducing the development cycle. The TDS Workshop can be used for TDS pens, water purifiers and other TDS application development.

1.1 Overall Environment



1.2 Software

The TDS application development software includes the TDS Workshop and the HT-IDE3000.

1.2.1 TDS Workshop

The TDS Workshop is used for master MCU selection, MCU resource configuration, TDS and NTC functional configuration, code generation, TDS data calibration and real-time monitoring, etc.

1.2.2 HT-IDE3000

The HT-IDE3000 is used to view and edit the source code which can be downloaded to the development board through the e-Link.

1.3 Hardware

The TDS application development hardware includes a TDS Workshop supporting evaluation board for which an e-Link is provided for emulation and downloading programs. Users can also develop their own unique development board according to their actual requirements.

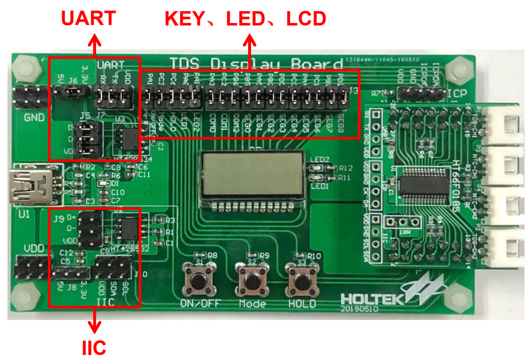
1.3.1. TDS Workshop Supporting Evaluation Board

The TDS Workshop supporting evaluation board contains a display board and TDS modules. Refer to the Appendix chapter for the physical pictures of the display board and TDS modules.

TDS Display Board

The display board contains a USB interface which is used as the power supply and for communication with the platform. It also includes a USB-to-UART bridge circuit and a USB-to-IIC bridge circuit for platform communication, three keys, an LCD (default: 3COM×9SEG), two LED alarm indicators, a module interface where a TDS module can be connected for test purposes, an ICP interface and a power supply interface.

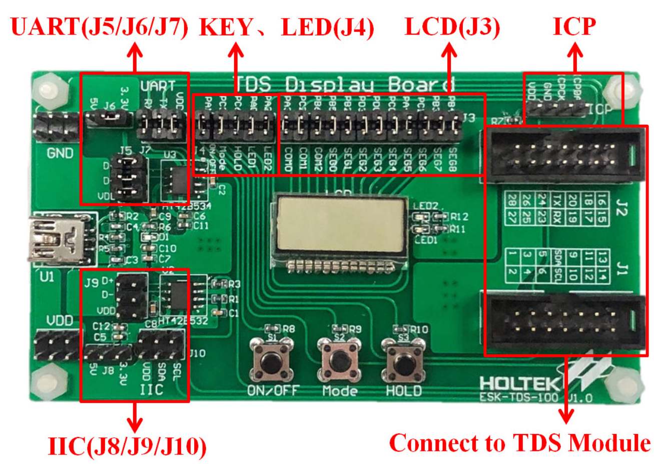
Display board connection:



The three keys, LCD and two alarm indicators on the display board can be used for functional testing purposes. If the corresponding function is directly connected by a mini jumper, users should use the default I/O pin configuration for the MCU on the platform. However, if the I/O pin configuration for the corresponding function is modified and requires functional testing, use Dupont lines for connection and testing.

UART communication hardware connection description:

- Connect J6 to the 5V or 3.3V power supply using a mini jumper – select the MCU operating voltage.
- Place mini jumpers on J5 and J7 to connect their individual communication pins and the VDD pin. In this way the USB and the HT42B534-2 UART communication pins and the VDD pin will be connected to the MCU.
- If the UART communication method is selected, the mini jumpers on J8, J9 and J10 of the IIC interface must all be removed to prevent circuit interference.
- The UART connection is shown below:



IIC communication hardware connection description:

- Connect J8 to the 5V or 3.3V power supply using a mini jumper – select the MCU operating voltage.
- Place mini jumpers on J9 and J10 to connect their individual communication pins and the VDD pin. In this way the USB and the HT42B532-1 IIC communication pins and the VDD pin will be connected to the MCU.
- If the IIC communication method is selected, the mini jumpers on J5, J6 and J7 of the UART interface must all be removed to prevent circuit interference.
- Refer to the UART communication connection for the IIC communication connection.

TDS Modules

① TDS Modules (HT66F0185/HT66F3185/HT66F3195): These modules are used when the master MCU is the HT66F0185, HT66F3185 or HT66F3195. These modules support single-channel and dual-channel TDS and NTC applications. The LCD and KEY functions are available for single-channel TDS applications. Functional verification can be conducted by combining the LCD and KEY functions on the display board. Either the UART or IIC can be used for communication.

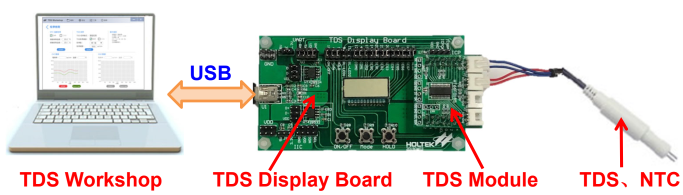
Note: When the TDS Modules HT66F0185/HT66F3185/HT66F3195 select the dual-channel mode and work together with the display board, the mini jumpers on the KEY, LCD and LED interfaces, i.e., J3 and J4, must all be removed to prevent circuit interference from causing functional abnormalities.

② TDS Modules (HT66F0176/HT66F2030): These modules are used when the master MCU is the HT66F0176 or HT66F2030. These modules support single-channel TDS and NTC applications, however they do not support the display board LCD, LED and KEY functions. Either the UART or IIC can be used for communication.

③ TDS Module (HT66F019): This module is used when the master MCU is the HT66F019. This module supports single-channel and dual-channel TDS and NTC applications, however it does not support the display board LCD, LED and KEY functions. Either the UART or IIC can be used for communication.

The toggle switches on their back side are used to connect the TDS CH1/CH2 and NTC CH1/CH2 to the corresponding MCU pins. When the module's TDS CH2 or NTC CH1/CH2 is not configured, the corresponding toggle switches must be turned off. Otherwise the acquisition circuit corresponding to the unused channel may conflict with other circuits resulting in functional abnormalites.

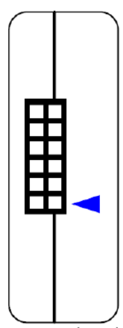
1.3.2. Hardware Connection Diagram



1.3.3. e-Link Connection

e-Link pin description:

e-Link（side）

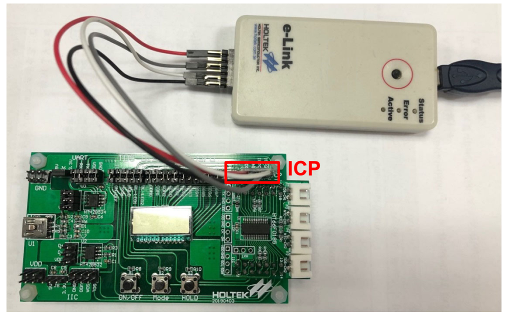


e-Link（side）

12: -	11: GND
10: -	9: OCDSDA
8: -	7: X
6: -	5: OCDSCK
4: -	3: -
2: -	1: VDD

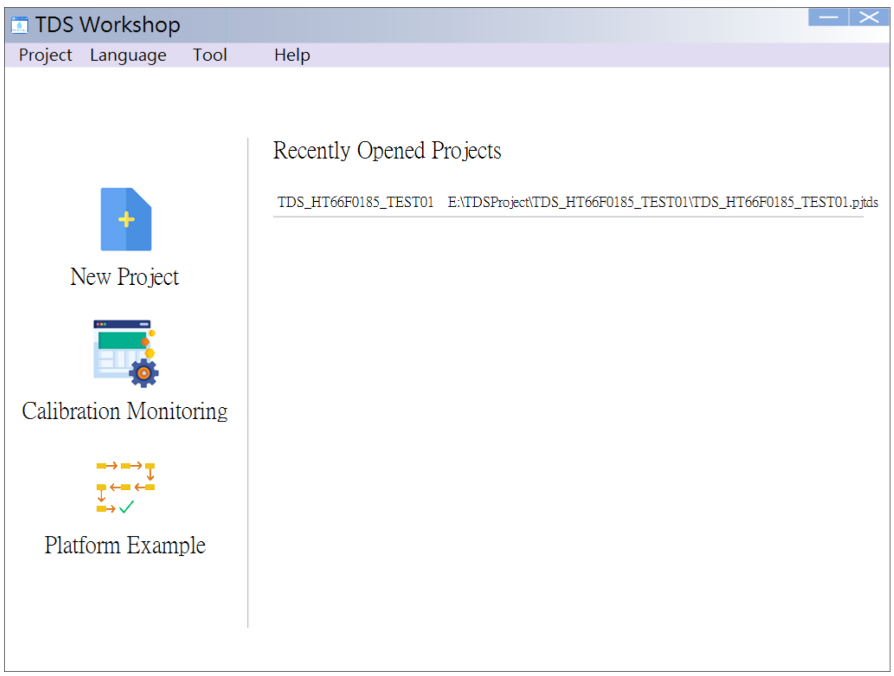
Hardware connection diagram:

Connect the ICP interface on the evaluation board to the corresponding pins of the e-Link and then connect the e-Link to a PC through the USB interface to execute emulation and download programs.

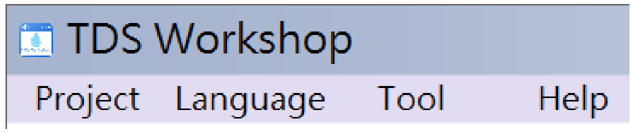


2 TDS Workshop Main Interface

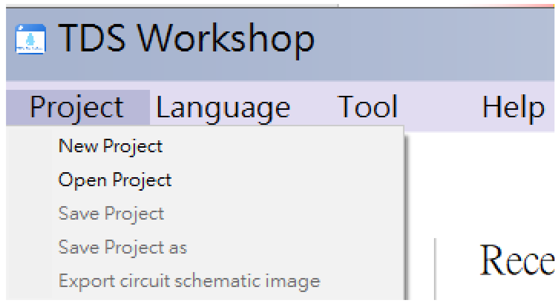
Double-click the TDS Workshop icon to open the TDS Workshop software. Its main interface contains several basic operation items including a Menu Bar, New Project, Platform Example and Calibration Monitoring as well as a list for recently opened projects, as shown below.



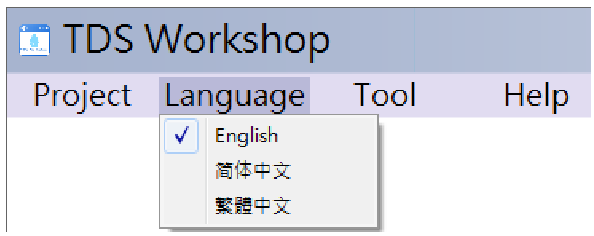
- New Project: Used to create a new HT-IDE3000 project and generate the corresponding project directory file.
- Platform Example: Used to open the platform's existing TDS product application examples.
- Calibration Monitoring: Used to open the Calibration Monitoring window for TDS product calibration and data monitoring.
- Recently Opened Projects: Users can open the recently used TDS Workshop projects directly from the list. Up to 20 open paths of the recently used files are available.
- Menu Bar: The menu bar contains Project, Language, Tool and Help options.



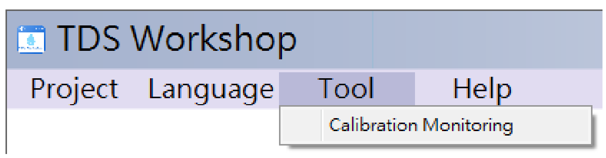
a. Project: Used to create, open and save projects as well as to export circuit schematic image.



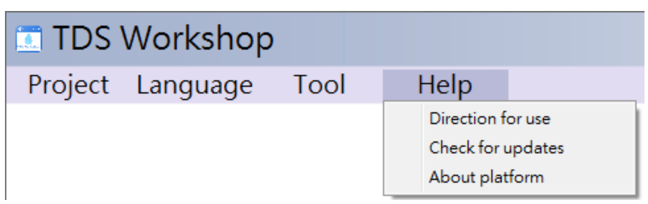
b. Language: The TDS Workshop supports three language options which are English, Simplified Chinese and Traditional Chinese.



c. Tool: The Calibration Monitoring window can be opened by clicking here.



d. Help: The TDS Workshop User Guide, platform version information and version update can be checked here.



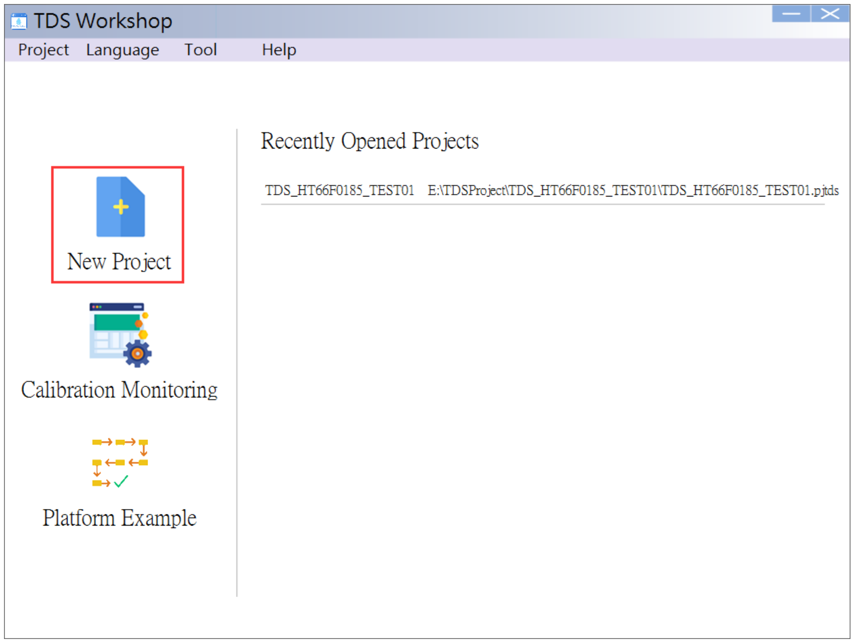
3 Create a New Project

Users can select a desired MCU part number and configure the TDS functions by creating a new project. More detailed steps are introduced in the following sections.

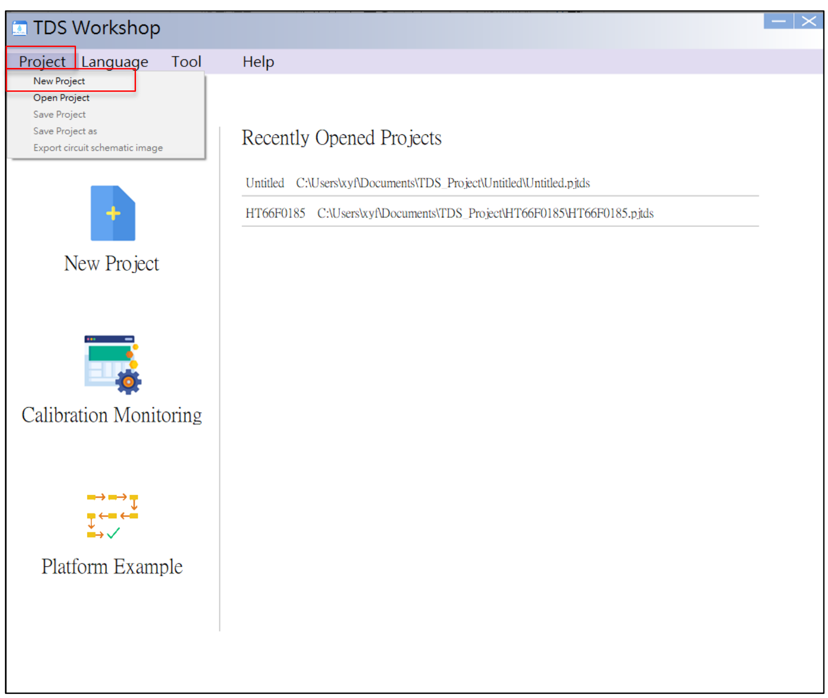
3.1 Create a New Project

There are two methods to create a new project.

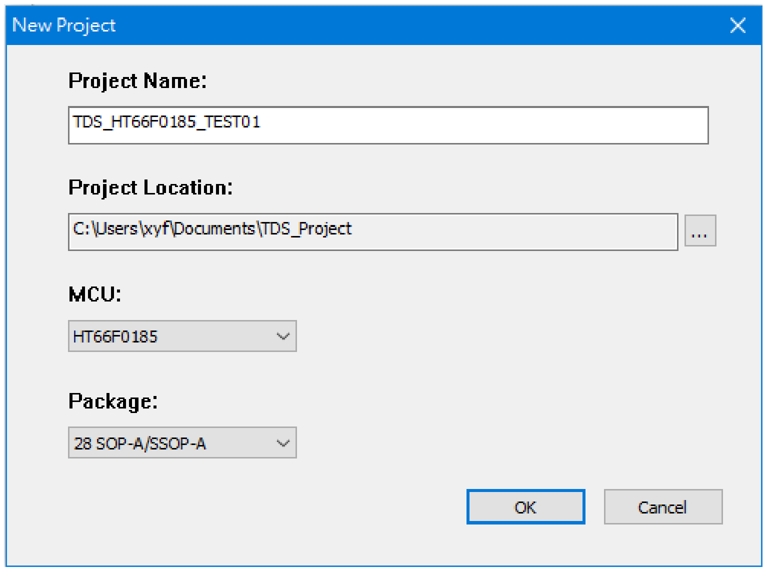
a. Click "New Project" icon on the main interface as shown below.



b. Menu: Project → New Project as shown below:



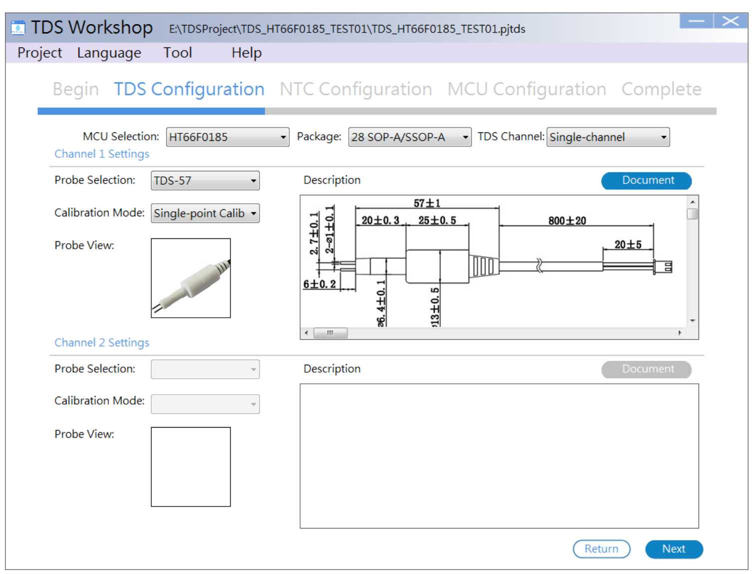
After clicking “New Project”, a New Project window will appear. Enter a project name, select a location for project file storage, select an MCU part number and its package type and then click “OK” to enter the project configuration interface.



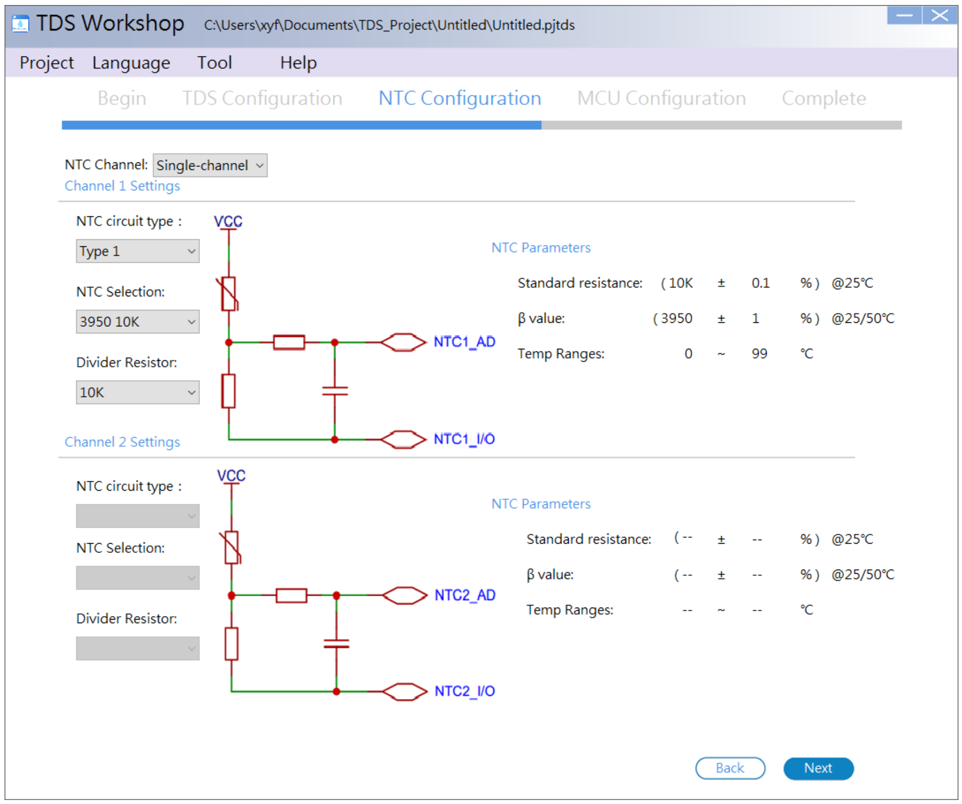
3.2 Project Configuration Interface

The TDS project configuration has four main operation steps, which are TDS Configuration, NTC Configuration, MCU Configuration and Complete. Detailed descriptions for each operation step are provided in the following sections.

TDS Configuration: The MCU part number and its package type (MCUs supported by this platform will continue to be updated), TDS channel count, probe type and calibration mode are configured in this step. There are three probe types which are the TDS-37, TDS-57 and TDS-67. Additional probe options will be continuously added. The Description part contains the selected probe specification, which can be viewed by clicking the Document button on the right side. The calibration mode currently only supports single-point calibration. When the configuration is completed, click “Next” to go to the next configuration step.



NTC Configuration: The NTC channel, NTC circuit type, NTC selection and divider resistor are configured in this step. The NTC channel count can be up to two and should not be larger than the selected TDS channel count. There are two NTC circuit types, one is connecting to the MCU VDD through an I/O and the other is connecting to the MCU GND. For the TDS-37 probe, the NTC selection is fixed at 3435 10K. For the TDS-57/TDS-67 probes, the available NTC options are 3950 5K/10K/20K/50K/100K, and Self built R-T table which requires users to fill in the resistance values corresponding to NTC temperatures. After the NTC is selected, the relevant parameters will be listed on the right side. After the configuration has completed, click "Next" to go to the next configuration step.

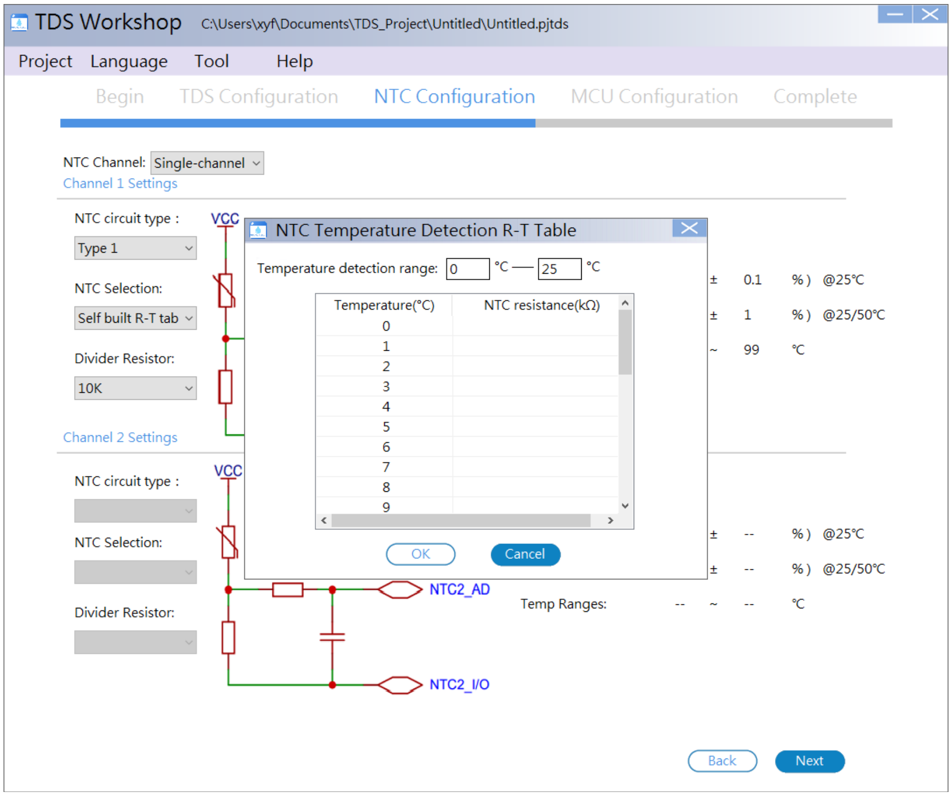


Both NTC circuit types support low power consumption requirements, such as battery power supply which requires to control the NTC circuit power supply. When NTC acquisition is not required, its power supply will be stopped to reduce power consumption. However, there existing an I/O internal resistance. For example, when the NTC circuit Type 2 is selected, the HT66F3185 I/O is connected to VDD (5V) to drive with a source current and the platform has set the source current to the maximum level, the I/O will have a maximum internal resistance of no more than 62.5Ω according to the following calculation formula. Due to the uncertain R_{IO}, in the case of a higher measurement temperature, the smaller the NTC resistance the larger the temperature error will be. This should also be considered when choosing the NTC circuit Type 1. If users have no power consumption requirements, connect the NTC circuit upper side to VDD and the lower side to GND to completely eliminate the influence of I/O internal resistance. The I/O internal resistance calculation of different MCUs can be referred to the following table.

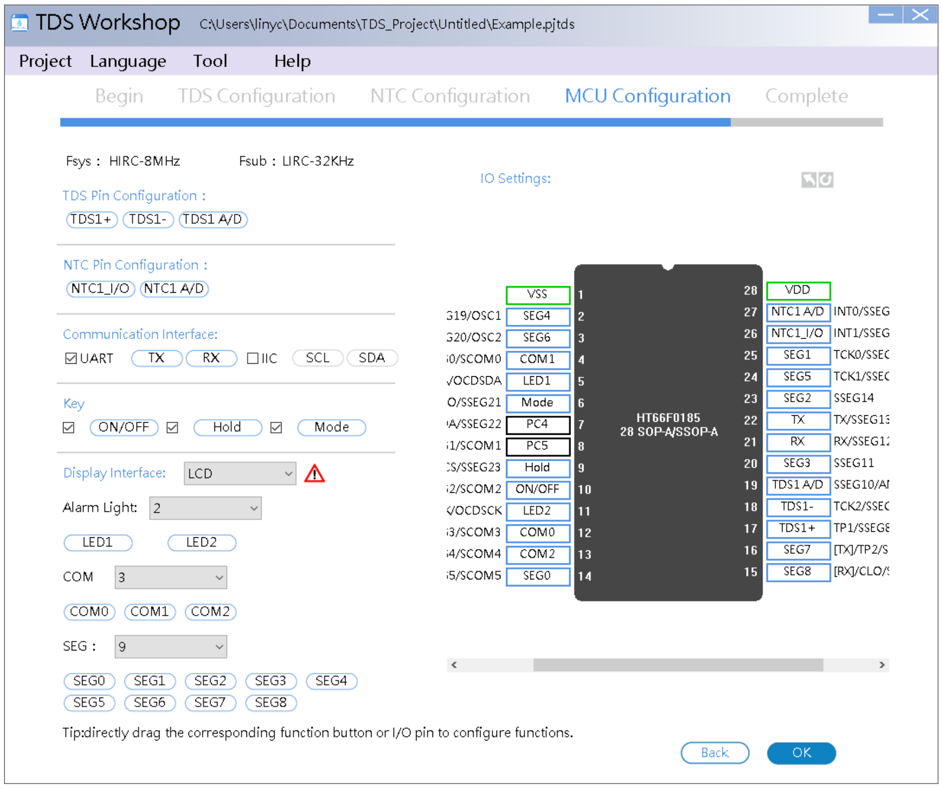
Module MCU	I_{OH}					R_{IO} Calculation
	V_{DD}	Condition	Min.	Typ.	Max.	
HT66F3195	5V	$V_{OH} = 0.9V_{DD}$	8mA	16mA	-	$R_{IO} = \frac{0.1V_{DD}}{I_{OH}}$
	3V		4mA	8mA	-	
HT66F3185	5V		8mA	16mA	-	
	3V		4mA	8mA	-	
HT66F2030	5V		8mA	16mA	-	
	3V		4mA	8mA	-	
HT66F0185	5V		11mA	22mA	-	
	3V		5.5mA	11mA	-	
HT66F0176	5V		11mA	22mA	-	
	3V		5.5mA	11mA	-	
HT66F019	5V		32mA	64mA	-	
	3V		16mA	32mA	-	

Module MCU	I_{OL}					R_{IO} Calculation
	V_{DD}	Condition	Min.	Typ.	Max.	
HT66F3195	5V	$V_{OL} = 0.1V_{DD}$	32mA	65mA	-	$R_{IO} = \frac{0.1V_{DD}}{I_{OL}}$
	3V		16mA	32mA	-	
HT66F3185	5V		32mA	65mA	-	
	3V		16mA	32mA	-	
HT66F2030	5V		32mA	65mA	-	
	3V		16mA	32mA	-	
HT66F0185	5V		32mA	64mA	-	
	3V		16mA	32mA	-	
HT66F0176	5V		32mA	64mA	-	
	3V		16mA	32mA	-	
HT66F019	5V		32mA	64mA	-	
	3V		16mA	32mA	-	

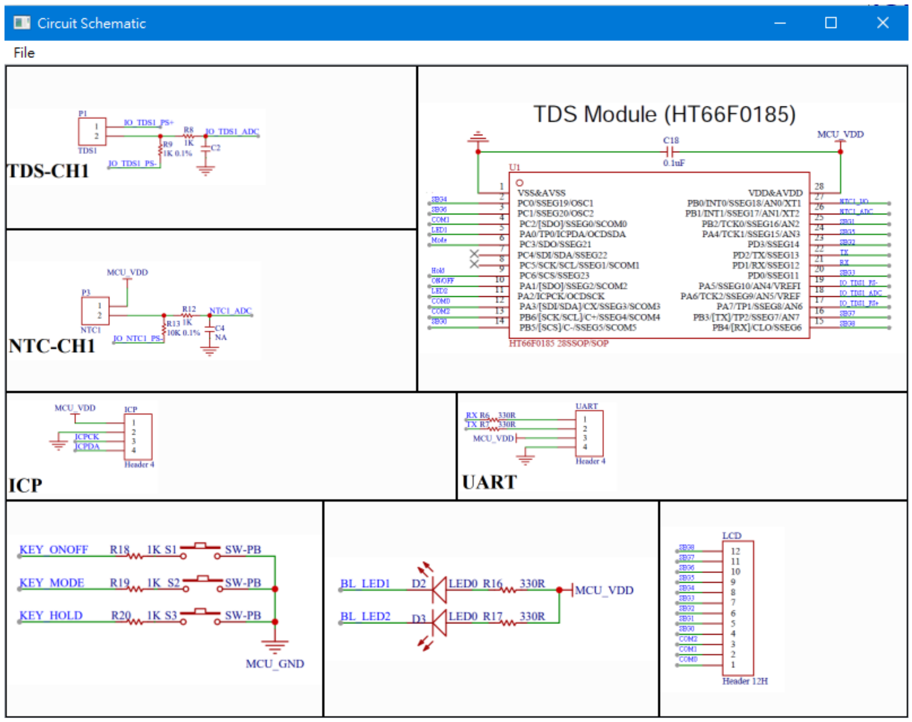
NTC Configuration – Self built R-T table: Users can choose this option to create their own R-T table to expand the NTC type selection. After clicking on this option, an R-T table window will pop up, where users need to fill in the temperature range and the corresesponding NTC resistance values. The higher the temperature, the smaller the resistance value is. Note that the temperature range should cover 25℃ and the maximum temperature range is 0℃~99℃.



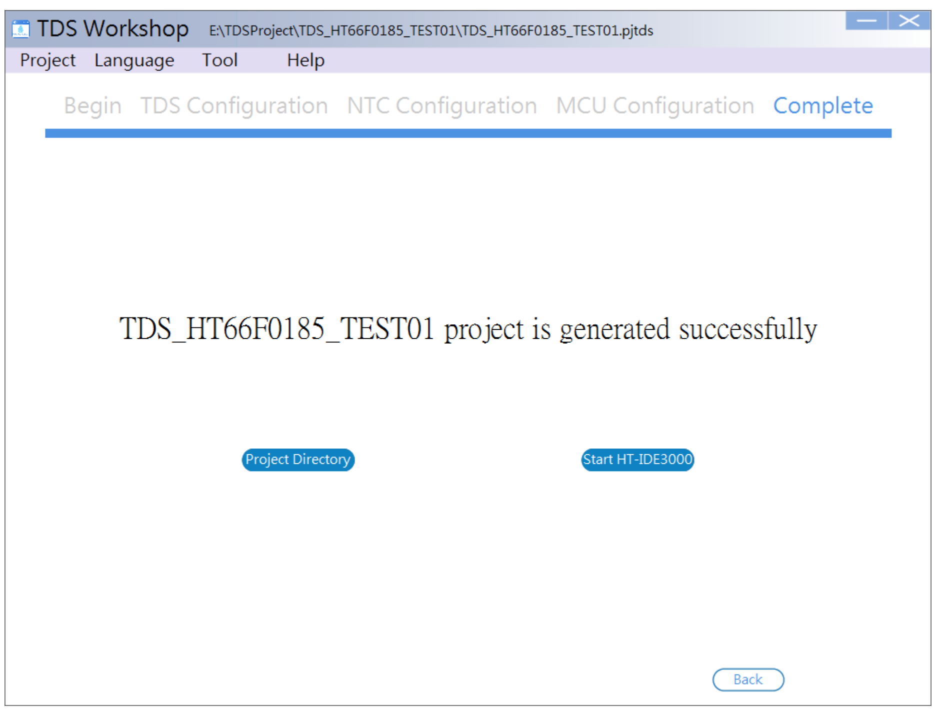
MCU Configuration: The TDS, NTC, communication method, key, alarm light, LCD and their functional pins are configured in this step. Either the UART or IIC interface is available for communication. For I/O pin configuration, directly drag the corresponding functional button to the desired pin location of the MCU diagram on the right. If any I/O pin configuration is changed, its pin box will change from blue to red. The green pin boxes indicate that the corresponding pin functions cannot be changed. Clicking the icon on the upper right side will undo the previous pin configuration and clicking the icon will restore the pin configuration previously undone. Then click "OK" to complete the TDS project creation.



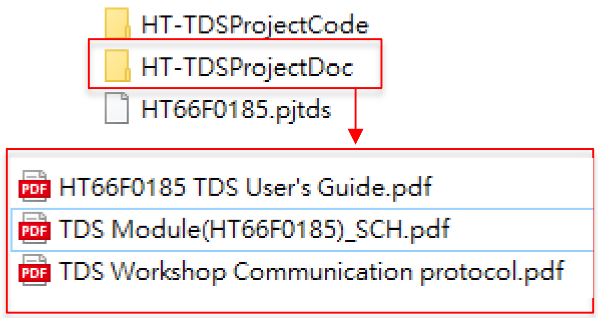
Export circuit schematic image: On the MCU Configuration inteface, users can click this option from the Project menu to preview the circuit schematic of the corresponding configuration. On the Circuit Schematic interface, users can click “File” to save or print the circuit schematic.



Complete: After a project configuration has finished, click “Project Directory” or “Start HT-IDE3000” button to directly open the program for editing and downloading. Clicking “Begin” will return to the initial interface. To reconfigure the project, click “Back”.



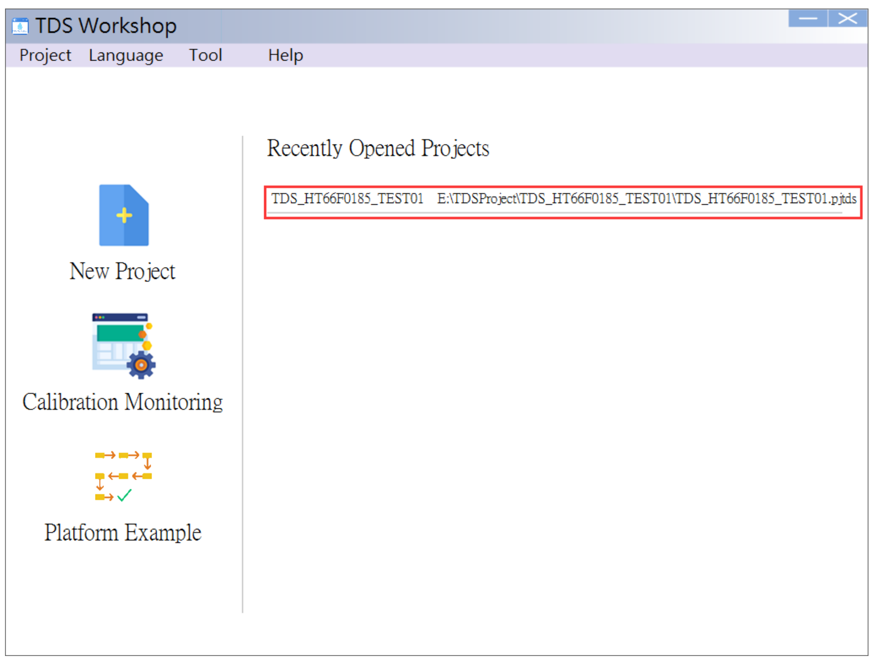
The generated project directory contains the following documents. The HT-TDSProjectCode is an HT-IDE3000 project folder. The HT-TDSProjectDoc folder contains the hardware description of the selected MCU and the TDS module communication protocol. The .pjtds file is a TDS Workshop project.



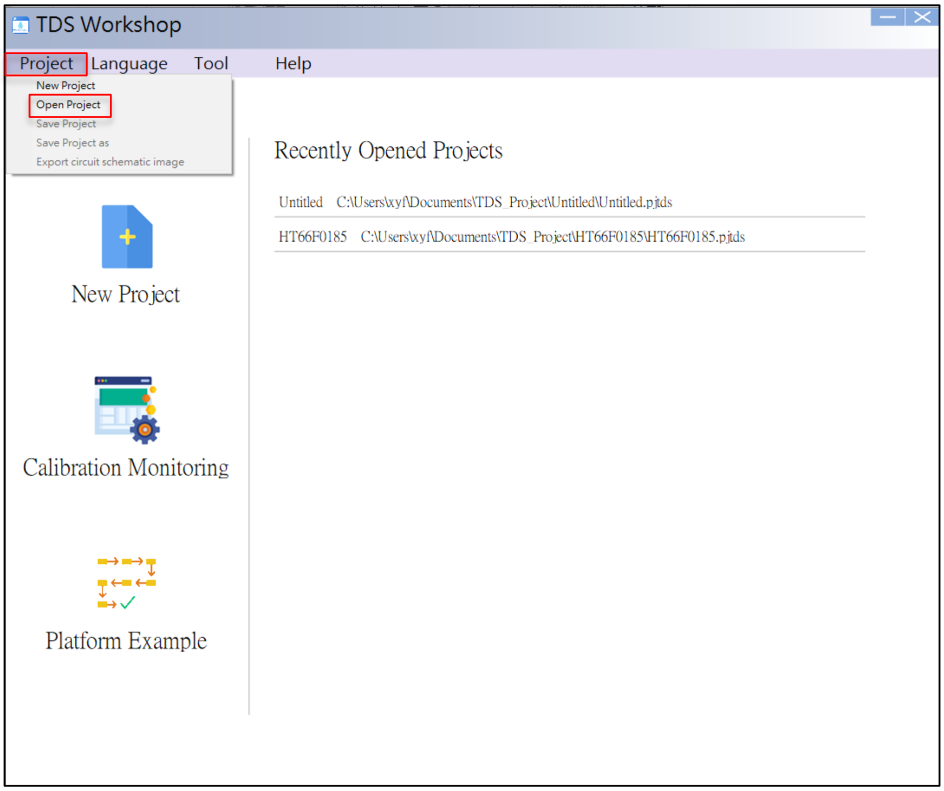
3.3 Open a Project

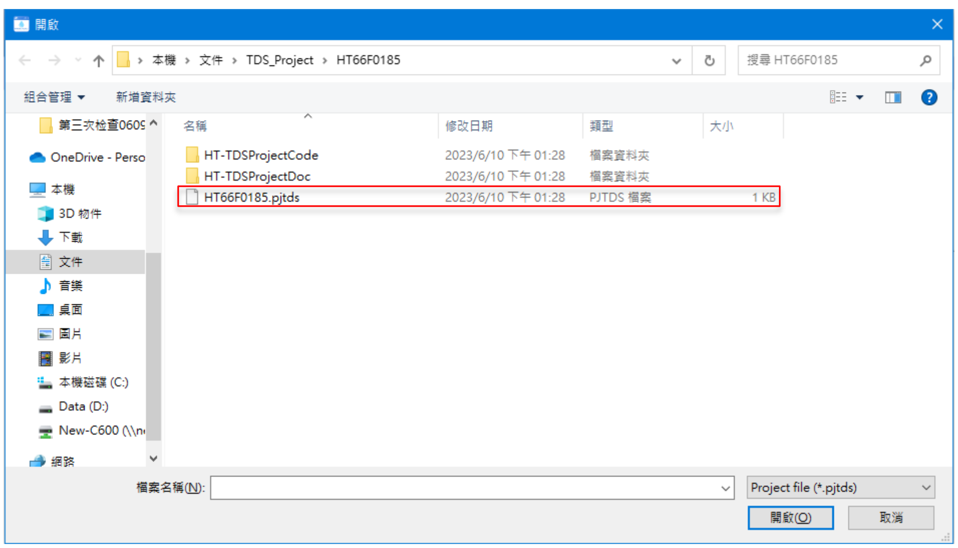
There are two methods to open a project.

a. Select the project to be opened directly from the "Recently Opened Projects" list. The TDS Workshop project file suffix is ".pjtds".



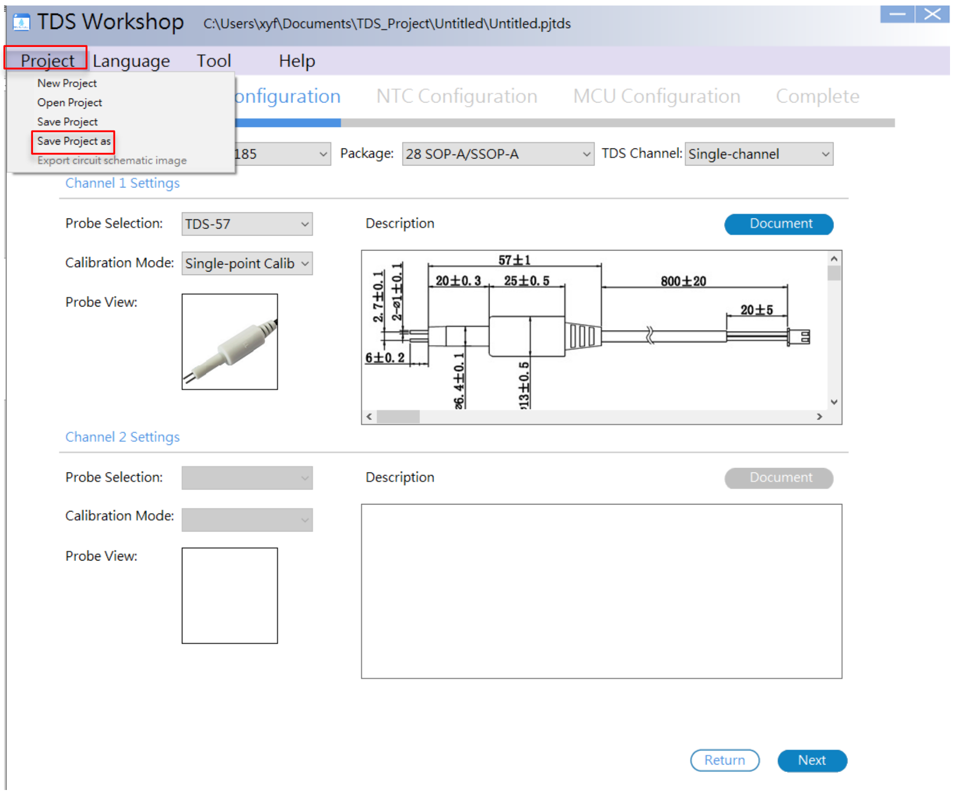
b. Menu: Project → Open Project, open the project file from the corresponding project location.





Open the project and enter the project configuration interface, which is the same as described in the "Create a New Project" section. Reconfigure the project or directly click "Next" without changing the configuration options, until the HT-IDE3000 project generation has completed.

As the new project file will overwrite the previous project, users can click "Project" → "Save Project as" to generate a new project directory and avoid overwriting the previous project.

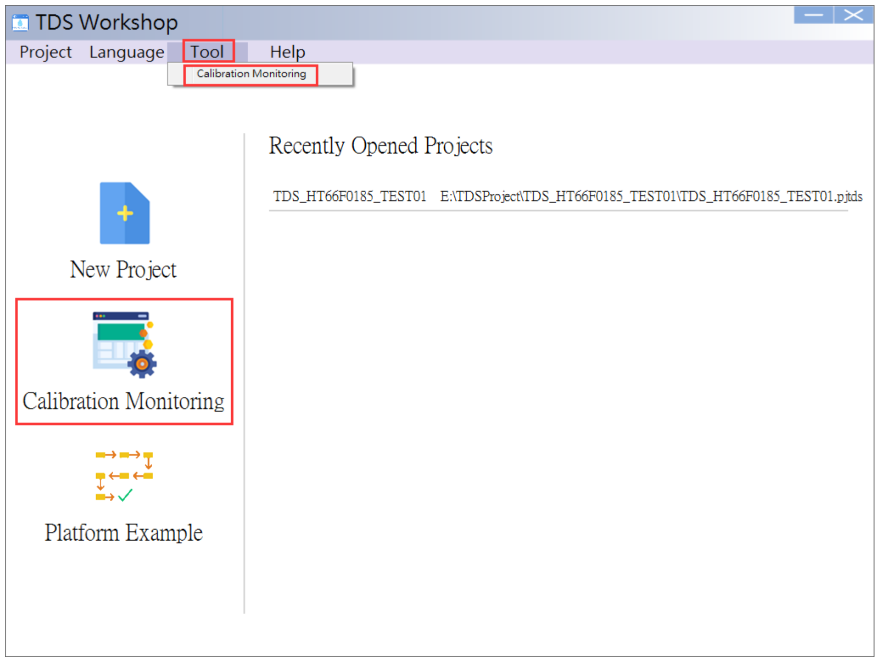


4 Calibration Monitoring

The calibration monitoring window can communicate with the development board to implement TDS and NTC calibration functions, real-time TDS value monitoring and test data exporting.

4.1. Calibration Monitoring Window

Users can directly click the "Calibration Monitoring" icon on the TDS Workshop main interface, or click "Tool" → "Calibration Monitoring". After this an operation window named "Calibration Monitoring" will pop up.

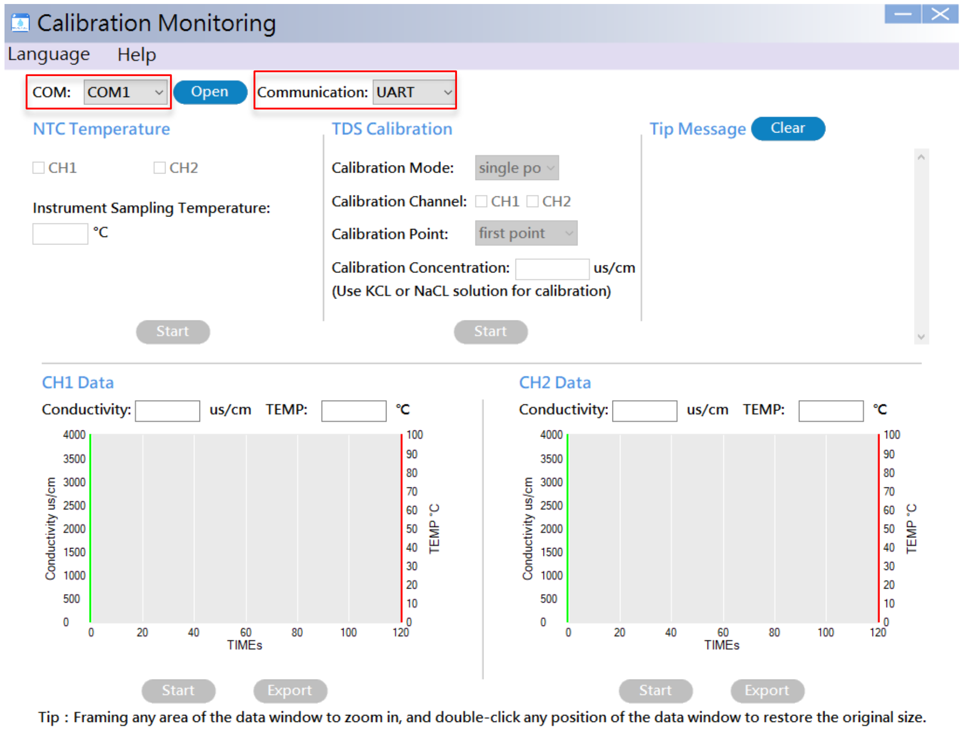


4.1.1 Calibration Monitoring Window Language Selection

The Language item in the menu bar allows users to select the Calibration Monitoring window language, which can be English, Simplified Chinese or Traditional Chinese.

4.1.2 Reading the Development Board Information

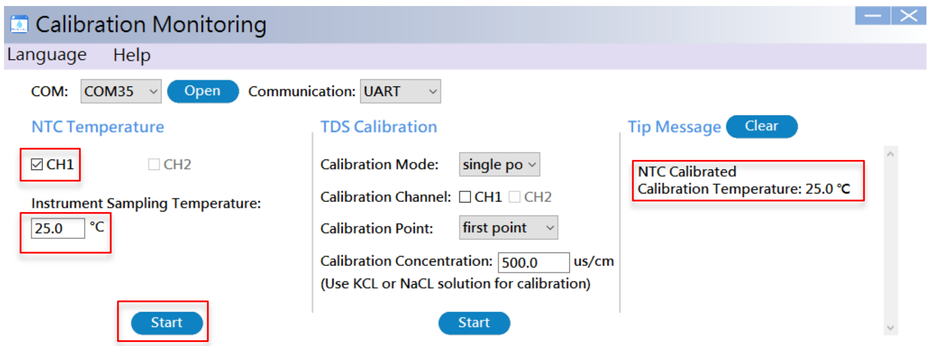
After the calibration monitoring window is opened, if the UART communication method is selected, the platform supports communication with the module through a third-party USB-to-UART device and users need to select the corresponding communication device serial port in the COM drop-down menu. If the IIC communication method is selected, the platform only sopports the module connected to the HT42B532-1 communication device.



Click the Open button to open the communication serial port. If the serial port is selected correctly, the platform will read the development board information and display it in the Tip Message area. The information includes the TDS channel count and calibration status, probe type, NTC channel count and calibration status.

4.1.3 NTC Temperature Calibration

Before starting the NTC calibration, first select the NTC channel to be calibrated, and then fill in a standard temperature value of the test solution into the “Instrument Sampling Temperature” field. The temperature value is 25.0°C by default and is accurate to one decimal fraction. By clicking on “Start” the development board will start to calibrate the NTC. After the calibration has finished, the Tip Message area will inform that NTC has been calibrated and display the calibrated temperature. If the calibration has failed, it will inform that the NTC calibration has failed. When this happens users should check whether the NTC is properly connected or not.



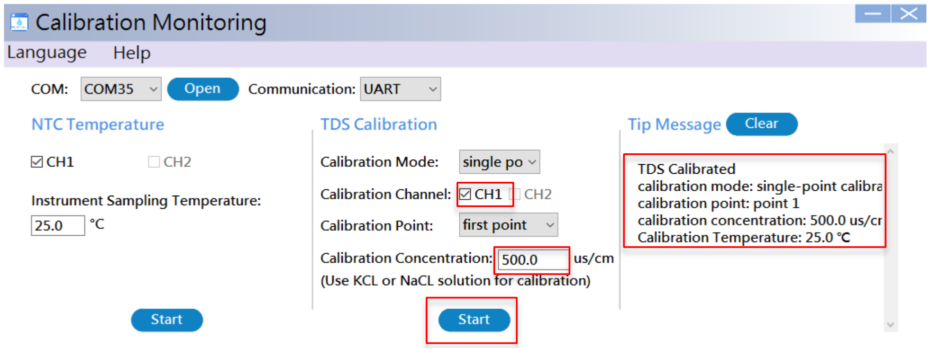
The NTC calibration information is stored in the EEPROM. The corresponding storage addresses are shown in the table below.

EEPROM Storage Addresses for NTC CH1 Calibration Information		
EEPROM Address	**Storage Contents**	**Description**
0x07	F_CAL_NTC1	0: NTC is not calibrated; 1: NTC is calibrated
0x08	S_CAL_NTC1 (higher 8 bits)	Standard solution temperature (higher 8 bits)
0x09	S_CAL_NTC1 (lower 8 bits)	Standard solution temperature (lower 8 bits)
0x0A	CAL_NTC1 (higher 8 bits)	Measured solution temperature (higher 8 bits)
0x0B	CAL_NTC1 (lower 8 bits)	Measured solution temperature (lower 8 bits)

EEPROM Storage Addresses for NTC CH2 Calibration Information		
EEPROM Address	**Storage Contents**	**Description**
0x17	F_CAL_NTC2	0: NTC is not calibrated; 1: NTC is calibrated
0x18	S_CAL_NTC2 (higher 8 bits)	Standard solution temperature (higher 8 bits)
0x19	S_CAL_NTC2 (lower 8 bits)	Standard solution temperature (lower 8 bits)
0x1A	CAL_NTC2 (higher 8 bits)	Measured solution temperature (higher 8 bits)
0x1B	CAL_NTC2 (lower 8 bits)	Measured solution temperature (lower 8 bits)

4.1.4 TDS Calibration

Before starting the TDS calibration, first select the TDS channel to be calibrated and then input a standard solution concentration value into the "Calibration Concentration" field. The concentration value is 500.0 us/cm by default and is accurate to one decimal fraction. The TDS calibration mode currently only supports single-point calibration. By clicking on "Start" the development board will start to calibrate the TDS. After the calibration has finished, the Tip Message area will inform that the TDS has been calibrated and display the calibrated concentration and temperature.



The TDS calibration information is stored in the EEPROM. The corresponding storage addresses are shown in the table below.

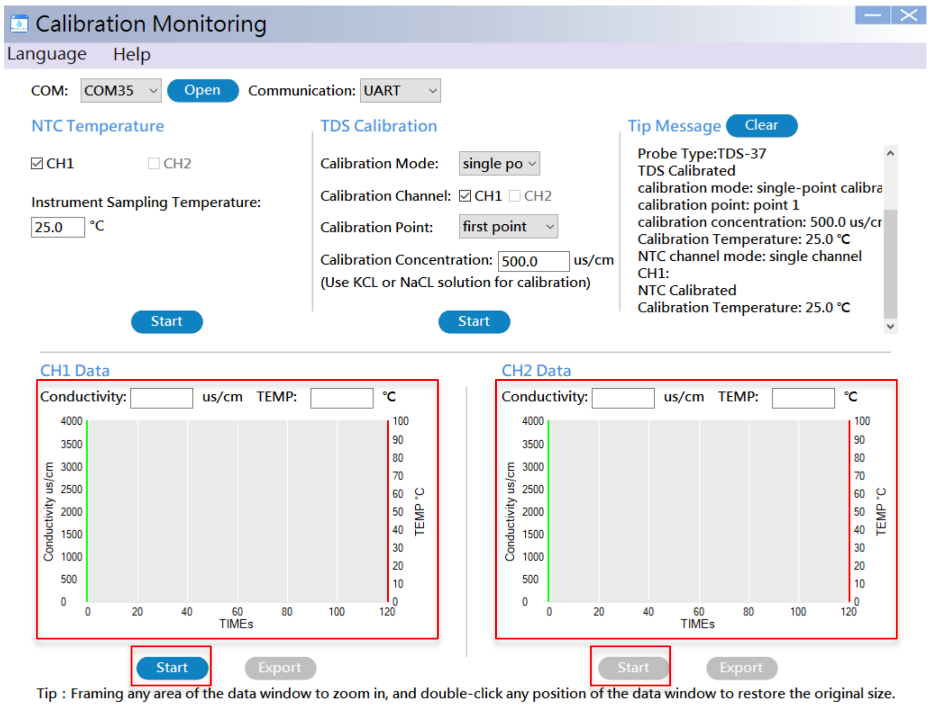
EEPROM Storage Addresses for TDS CH1 Calibration Information		
EEPROM Address	Storage Contents	Description
0x00	F_CAL_TDS1	0: TDS is not calibrated; 1: TDS is calibrated
0x01	S_CAL_TDS1 (higher 8 bits)	Standard solution concentration (higher 8 bits)
0x02	S_CAL_TDS1 (lower 8 bits)	Standard solution concentration (lower 8 bits)
0x03	CAL_TDS1 (higher 8 bits)	Measured solution concentration (higher 8 bits)
0x04	CAL_TDS1 (lower 8 bits)	Measured solution concentration (lower 8 bits)
0x05	CAL_TEMP1 (higher 8 bits)	Solution temperature during TDS calibration (higher 8 bits)
0x06	CAL_TEMP1 (lower 8 bits)	Solution temperature during TDS calibration (lower 8 bits)

EEPROM Storage Addresses for TDS CH2 Calibration Information		
EEPROM Address	Storage Contents	Description
0x10	F_CAL_TDS2	0: TDS is not calibrated; 1: TDS is calibrated
0x11	S_CAL_TDS2 (higher 8 bits)	Standard solution concentration (higher 8 bits)
0x12	S_CAL_TDS2 (lower 8 bits)	Standard solution concentration (lower 8 bits)
0x13	CAL_TDS2 (higher 8 bits)	Measured solution concentration (higher 8 bits)
0x14	CAL_TDS2 (lower 8 bits)	Measured solution concentration (lower 8 bits)
0x15	CAL_TEMP2 (higher 8 bits)	Solution temperature during TDS calibration (higher 8 bits)
0x16	CAL_TEMP2 (lower 8 bits)	Solution temperature during TDS calibration (lower 8 bits)

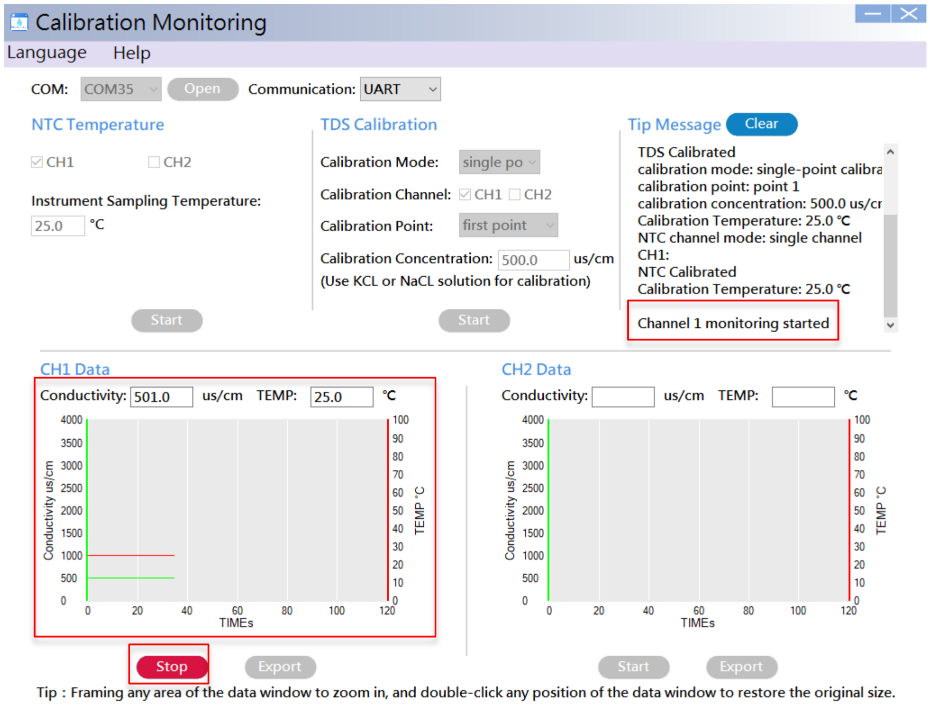
The TDS calibration can be implemented using KCL or NaCL solutions. In addition, users can select a suitable standard solution concentration for calibration according to the TDS measurement range. For example, for a measurement range of 0~1000PPM, a 400~600PPM standard solution can be used for TDS calibration.

4.1.5 TDS Data Monitoring

"CH1 Data" and "CH2 Data" are the TDS channel 1 and channel 2 data monitoring windows respectively. The two channels can be monitored simultaneously in the dual-channel TDS mode. Clicking the "Start" button at the bottom of the corresponding monitoring window will start the channel TDS data monitoring. If the "Start" button appears gray, this means that TDS data monitoring is not available for the corresponding channel.



When the platform starts TDS data monitoring, the Tip Message area will indicate "Channel 1 (or Channel 2) monitoring started". In the monitoring window, a curve chart shows the conductivity and temperature values read by the platform. Up to 120 values can be displayed. The x-coordinate moves backward with more data being read. The green curve indicates the conductivity value based on the green coordinate on the left and the red curve indicates the temperature value based on the red coordinate on the right. To view data more clearly, hold the left mouse button and drag the cursor to the lower right to select the area to be enlarged. Holding the left mouse button and dragging the cursor to the upper left will return to the initial size of the chart window. The conductivity and temperature values displayed on the top of the curve chart are the newly read values.



After stopping monitoring, click the "Export" button to export the read data to an excel spreadsheet.

The exported excel spreadsheet includes test data such as time, temperature and conductivity, as shown below.

	A	B	C	D
1	TIME(s)	TEMP(˚C)	Conductivity(us/cm)	
2	0	24.4	489.5	
3	1	24.4	489.5	
4	2	24.4	489.5	
5	3	24.4	489.5	
6	4	24.4	489.5	
7	5	24.4	489.5	
8	6	24.4	489.5	
9	7	24.4	489.5	
10	8	24.4	489.5	
11	9	24.4	489.5	
12	10	24.4	489.5	

5 Platform Example

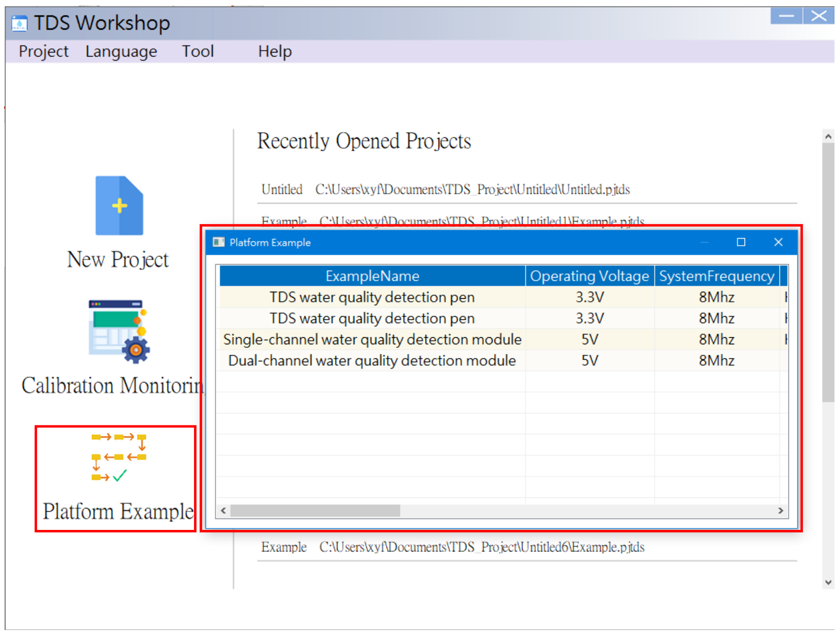
The platform provides the Holtek TDS product application examples. Users can export the desired application project example for reference according their actual development requirements.

Measurement ranges of the platform examples:

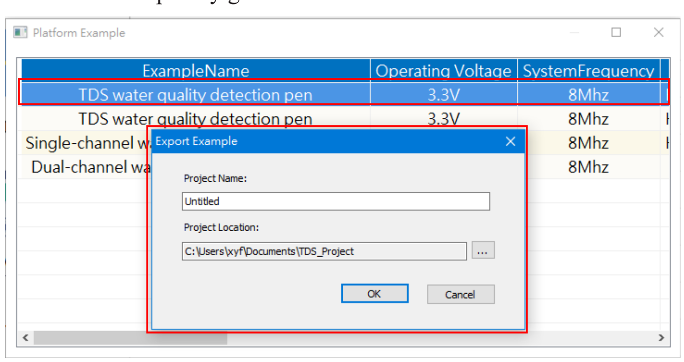
- Temperature measurement range: 0~99°C
- TDS measurement range: 0~2000PPM
- TDS measurement accuracy: ±5%

5.1. Exporting a Platform Example

Click the "Platform Example" icon on the main interface to open the "Platform Example" window.



The platform example table lists the operating voltage, system frequency, MCU part number, TDS setting, NTC setting and other parameters. Single-click on any one of the examples and an "Export Example" window will pop up. Edit the project name and select the project file storage location. Then click "OK" to enter the project configuration interface which is the same as described in the "Create a New Project" section. According to the actual application requirements, users can reconfigure the project or click "Next" without changing the configuration options, until the HT-IDE3000 project has been completely generated.



6 Library Function Description

The TDS libraries for each MCU currently provided by the platform are shown below. Selecting different applications on the platform will automatically generate the corresponding libraries.

MCU	TDS Libraries	Description
HT66F0185	HT66F0185_S_TDS.lib	HT66F0185 single-channel TDS library
	HT66F0185_D_TDS.lib	HT66F0185 dual-channel TDS library
HT66F0176	HT66F0176_S_TDS.lib	HT66F0176 single-channel TDS library
HT66F019	HT66F019_S_TDS.lib	HT66F019 single-channel TDS library
	HT66F019_D_TDS.lib	HT66F019 dual-channel TDS library
HT66F3185	HT66F3185_S_TDS.lib	HT66F3185 single-channel TDS library
	HT66F3185_D_TDS.lib	HT66F3185 dual-channel TDS library
HT66F3195	HT66F3195_S_TDS.lib	HT66F3195 single-channel TDS library
	HT66F3195_D_TDS.lib	HT66F3195 dual-channel TDS library
HT66F2030	HT66F2030_S_TDS.lib	HT66F2030 single-channel TDS library

6.1 TDS Macro Definitions and Library Functions

The platform will generate the following definitions based on the TDS configuration:

- Fun_TDS1 and Fun_TDS2 are defined in the define.h file, where 37/57/67 indicates the corresponding probe type. Only Fun_TDS1 is defined if single-channel mode is selected.

```
#define    Fun_TDS1    37
#define    Fun_TDS2    37
```

- The TDS related configurations are defined in the IO_define.h file. TDSn_POS_ADDR and TDSn_NEG_ADDR define the input/output port data register addresses of the TDS pulse pins. TDSn_POS_OFFSET_ADDR and TDSn_NEG_OFFSET_ADDR define the configuration values of these input/output port data registers. TDSn_AD_CHANEL defines the TDS AD acquisition channel. TDSn_IO_MULTI_ADDR defines the pin-shared control register address of the TDS AD acquisition pin. TDSn_IO_MULTI defines the pin-shared control register configuration value of the TDS AD acquisition pin.

```
#define TDS1_POS_ADDR          0X14    TDS1 pulse pin configuration
#define TDS1_POS_OFFSET_ADDR   0X80
#define TDS1_NEG_ADDR          0X14
#define TDS1_NEG_OFFSET_ADDR   0X20
#define TDS1_AD_CHANEL         5       TDS1 AD acquisition pin configuration
#define TDS1_IO_MULTI_ADDR     0x44
#define TDS1_IO_MULTI          0x20
#define TDS2_POS_ADDR          0X41    TDS2 pulse pin configuration
#define TDS2_POS_OFFSET_ADDR   0X04
#define TDS2_NEG_ADDR          0X14
#define TDS2_NEG_OFFSET_ADDR   0X02
#define TDS2_AD_CHANEL         3       TDS2 AD acquisition pin configuration
#define TDS2_IO_MULTI_ADDR     0x44
#define TDS2_IO_MULTI          0x08
```

The TDS libraries include the following functions.

Function	Description
TDS_Init()	TDS initialisation function
Start_TDS1()	TDS channel 1 acquisition function
Start_TDS2()	TDS channel 2 acquisition function
Get_TDS_C1_K()	TDS channel 1 conductivity calculation function
Get_TDS_C2_K()	TDS channel 2 conductivity calculation function
GET_NTC1_Value()	Temperature acquisition function, returns the temperature value directly

6.1.1 TDS Initialisation Function

The TDS_Init() function is used for TDS pin and parameter initialisation.

6.1.2 TDS Acquisition Functions

The Start_TDS1() and Start_TDS2() functions are used to start the TDS ADC function and implement TDS acquisition. Start_TDS1() is for TDS channel 1 and Start_TDS2() is for channel 2. If the single-channel option is selected, it corresponds to the channel 1 function.

6.1.3 TDS Calculation Functions

The Get_TDS_C1_K() and Get_TDS_C2_K() functions are used to process the TDS data and calculate the TDS conductivity values.

Get_TDS_C1_K() is for TDS channel 1 and Get_TDS_C2_K() is for channel 2. After the calculation has finished, the corresponding flag, F_TDS1Count_Done for channel 1 and F_TDS2Count_Done for channel 2, will be set to “1”. The channel results will be magnified 10 times and stored in the U16_TDS1_k and U16_TDS2_k variables respectively (unit: us/cm).

The results obtained by the calculation function have not been temperature compensated and TDS calibrated. The temperature compensation and calibration functions are defined in the process.c file. Compensation_TDS1() and Compensation_TDS2() are the temperature compensation functions. The conductivity value after temperature compensation is stored in the U16_TDS1_k and U16_TDS2_k respectively. TDS_fun_handle() is the calibration function. The TDS calibrated result is stored in TDS1_K for channel 1 and TDS2_K for channel 2. Here the temperature compensation and calibration results (unit: us/cm) both are 10 times their raw values.

6.1.4 Temperature Acquisition Macro Definitions and Functions

The platform will generate the following definitions based on the NTC configuration:

- Fun_NTC1 and Fun_NTC2 are defined in the define.h file. Only Fun_NTC1 is defined if single-channel mode is selected.

```
#define      Fun_NTC1
#define      Fun_NTC2
```

- The NTC related configurations are defined in the IO_define.h file. NTCn_IO_MULTI_ADDR defines the pin-shared control register address of the NTC AD acquisition pin. NTCn_IO_MULTI defines the pin-shared control register configuration value of the NTC AD acquisition pin. NTCn_sadc0, NTCn_sadc1 and NTCn_sadc2 configure the NTC AD conversion registers.

#define NTC1_TYPE	2	NTC1 circuit type
#define NTC1_TOP #define NTC1_FLOOR	27 0	NTC1 temp. upper/lower limit
#define NTC1_IO #define NTC1_IOC	_pb0 _pbc0	NTC1 circuit control I/O
#define NTC1_IO_MULTI_ADDR #define NTC1_IO_MULTI	0x44 0x02	NTC1 AD acquisition pin configuration
#define NTC1_sadc0 #define NTC1_sadc1 #define NTC1_sadc2	0x11 0x03 0x00	NTC1 AD conversion register configuration
#define NTC2_TYPE	2	NTC2 circuit type
#define NTC2_TOP #define NTC2_FLOOR	99 0	NTC2 temp. upper/lower limit
#define NTC2_IO #define NTC2_IOC	_pb5 _pbc5	NTC2 circuit control I/O
#define NTC2_IO_MULTI_ADDR #define NTC2_IO_MULTI	0x44 0x04	NTC2 AD acquisition pin configuration
#define NTC2_sadc0 #define NTC2_sadc1 #define NTC2_sadc2	0x12 0x03 0x00	NTC2 AD convertion register configuration

- The temperature AD values are stored in the NTC_Table.h file.

```
const unsigned int NTC1_table[] =
{
    980,1017,1054,1093,1132,1172,1212,1253,1295,1336,
    1379,1422,1466,1509,1554,1598,1642,1687,1732,1777,
    1822,1868,1912,1958,2002,2047,2091,2136,2180,2223,
    2266,2309,2352,2393,2435,2476,2516,2556,2595,2633,
    2671,2708,2745,2781,2816,2851,2884,2917,2950,2981,
    3012,3043,3072,3101,3129,3156,3183,3209,3234,3259,
    3283,3306,3329,3351,3372,3393,3414,3433,3452,3471,
    3489,3506,3523,3540,3556,3571,3586,3601,3615,3629,
    3642,3655,3667,3679,3691,3702,3713,3724,3734,3744,
    3754,3763,3772,3781,3789,3797,3806,3813,3821,3828
};
const unsigned int NTC2_table[] =
{
    980,1017,1054,1093,1132,1172,1212,1253,1295,1336,
    1379,1422,1466,1509,1554,1598,1642,1687,1732,1777,
    1822,1868,1912,1958,2002,2047,2091,2136,2180,2223,
    2266,2309,2352,2393,2435,2476,2516,2556,2595,2633,
    2671,2708,2745,2781,2816,2851,2884,2917,2950,2981,
    3012,3043,3072,3101,3129,3156,3183,3209,3234,3259,
    3283,3306,3329,3351,3372,3393,3414,3433,3452,3471,
    3489,3506,3523,3540,3556,3571,3586,3601,3615,3629,
    3642,3655,3667,3679,3691,3702,3713,3724,3734,3744,
    3754,3763,3772,3781,3789,3797,3806,3813,3821,3828
};
```

The temperature acquisition functions are defined in the Temp.c file. GET_NTC1_Value() corresponds to NTC channel 1 and GET_NTC2_Value() corresponds to NTC channel 2. These functions will return the temperature value (unit: °C) directly, which is 10 times the actual value.

6.2 Communication Description

The TDS modules support either the UART or IIC communication with the platform, which is respectively implemented by connecting the USB-to-UART (HT42B534-2) or USB-to-IIC (HT42B532-1) bridge on the display board to the USB.

6.2.1 Macro Definitions and Communication Protocol

When the UART or IIC communication interface is selected on the platform, Fun_Communicate and Fun_UART or Fun_IIC in the define.h file will be defined.

```
#define Fun_UART
#define Fun_Communicate
```

The communication pins are defined in the IO_define.h file, as shown below.

MCU	Pin Definition	Value	Communication Pin
HT66F0185	UART_TX	0x00	Select PD2 as TX pin
		0x02	Select PB3 as TX pin
	UART_RX	0x00	Select PD1 as RX pin
		0x01	Select PB4 as RX pin
	IIC_SDA	0x00	Select PC4 as SDA pin
		0x10	Select PA3 as SDA pin
	IIC_SCL	0x00	Select PC5 as SCL pin
		0x08	Select PB6 as SCL pin
HT66F0176	UART_TX	0x00	Select PC6 as TX pin
		0x02	Select PB3 as TX pin
	UART_RX	0x00	Select PC5 as RX pin
		0x01	Select PB4 as RX pin
	IIC_SDA	0x00	Select PC3 as SDA pin
		0x10	Select PA3 as SDA pin
	IIC_SCL	0x00	Select PC4 as SCL pin
		0x08	Select PB6 as SCL pin
HT66F019	UART_TX	0x00	Select PA6 as TX pin
		0x02	Select PB3 as TX pin
	UART_RX	0x00	Select PA7 as RX pin
		0x01	Select PB4 as RX pin
	IIC_SDA	—	PA3 is SDA pin
	IIC_SCL	—	PB6 is SCL pin
HT66F3185	UART_TX	0x00	Select PC0 as TX pin
		0x01	Select PC1 as TX pin
		0x02	Select PD1 as TX pin
		0x03	Select PD2 as TX pin
	UART_RX	0x00	Select PD1 as RX pin
		0x01	Select PC1 as RX pin
	IIC_SDA	0x00	Select PC4 as SDA pin
		0x01	Select PA3 as SDA pin
	IIC_SCL	0x00	Select PC5 as SCL pin
		0x01	Select PB6 as SCL pin
HT66F3195	UART_TX	0x00	Select PC0 as TX pin
		0x01	Select PD2 as TX pin
	UART_RX	0x00	Select PD1 as RX pin
		0x01	Select PC1 as RX pin
	IIC_SDA	0x00	Select PC4 as SDA pin
		0x01	Select PA3 as SDA pin
	IIC_SCL	0x00	Select PC5 as SCL pin
		0x01	Select PB6 as SCL pin

MCU	Pin Definition	Value	Communication Pin
HT66F2030	UART_RX	0x00	Select PA3 as RX pin
		0x01	Select PA7 as RX pin
		0x02	Select PB1 as RX pin
	UART_TX	0x00	Select PA5 as TX pin
		0x01	Select PA6 as TX pin
		0x02	Select PB2 as TX pin
	IIC_SDA	0x00	Select PA5 as SDA pin
		0x01	Select PB0 as SDA pin
		0x02	Select PB1 as SDA pin
	IIC_SCL	—	Select PB2 as SCL pin

UART definition example:

- In the define.h file:

```
#define Fun_Communicate    1
#define     Fun_UART       1
```

- In the IO_define.h file:

```
#define UART_TX       0x03
#define UART_RX       0x00
```

If the IIC communication method is selected, data reception and transmission are executed in the IIC interrupt subroutine. As for UART communication, data reception is executed in the UART interrupt subroutine and data transmission is implemented using the Send_Data() function. The Rx_Data_Handle() function is used to process the received data.

6.2.2 Communication Protocol

The communication between the TDS module and the platform is based on the protocol described in the following table. The TDS Workshop operates as a host and the TDS module operates as a slave. The host can request various operations, such as calibrating the TDS value and temperature value, obtaining the probe information, calibration information, TDS value and temperature value and requesting the module to enter the sleep mode.

TDS Water Quality Detection Module Communication Protocol					
Frame Format (applied to all communications)					
Character Type	Frame Header	Data Length	Command	Data	Checksum
Byte Count (byte)	1	1	1	L	1
Data	0x55	Length	Command	Data	Checksum
Description	Length: Length+Command+Data+Checksum total length=1+1+L+1; Data: high byte is transmitted first then low byte; Checksum: from the frame header to data, single byte accumulation.				

TDS Water Quality Detection Module Communication Protocol

Host Commands

1. Host obtains product information (Command:0x00)

Byte1	Byte2	Byte3	Byte4~7	Byte8
Frame Header	Length	Command	Data	Checksum
0x55	0x07	0x00	0x00	0x5C

Note: The obtained product information is mainly probe type related information.

2. Host obtains TDS calibration information (Command:0x01)

Byte1	Byte2	Byte3	Byte4	Byte5~7	Byte8
Frame Header	Length	Command	Data	Data	Checksum
0x55	0x07	0x01	…	0x00	…

Note: Byte4 indicates the TDS channel. Byte4=0x01 means to obtain the TDS calibration information of channel 1.

3. Host obtains NTC calibration information (Command:0x02)

Byte1	Byte2	Byte3	Byte4	Byte5~7	Byte8
Frame Header	Length	Command	Data	Data	Checksum
0x55	0x07	0x02	…	0x00	…

Note: Byte4 indicates the NTC channel. Byte4=0x01 means to obtain the NTC calibration information of channel 1.

4. Host sets the module to enter TDS calibration mode (Command:0x03)

Byte1	Byte2	Byte3	Byte4~7	Byte8
Frame Header	Length	Command	Data	Checksum
0x55	0x07	0x03	…	…

Note:

(1) Byte4 indicates the TDS channel. Byte4=0x01 means to set the TDS channel 1 to enter the calibration mode.

(2) Byte5 indicates the calibration mode and calibration points. Bit7 indicates the calibration mode; bit7=0 means single-point mode, bit7=1 means multi-point mode. Bit6~bit0 indicate the calibration point.

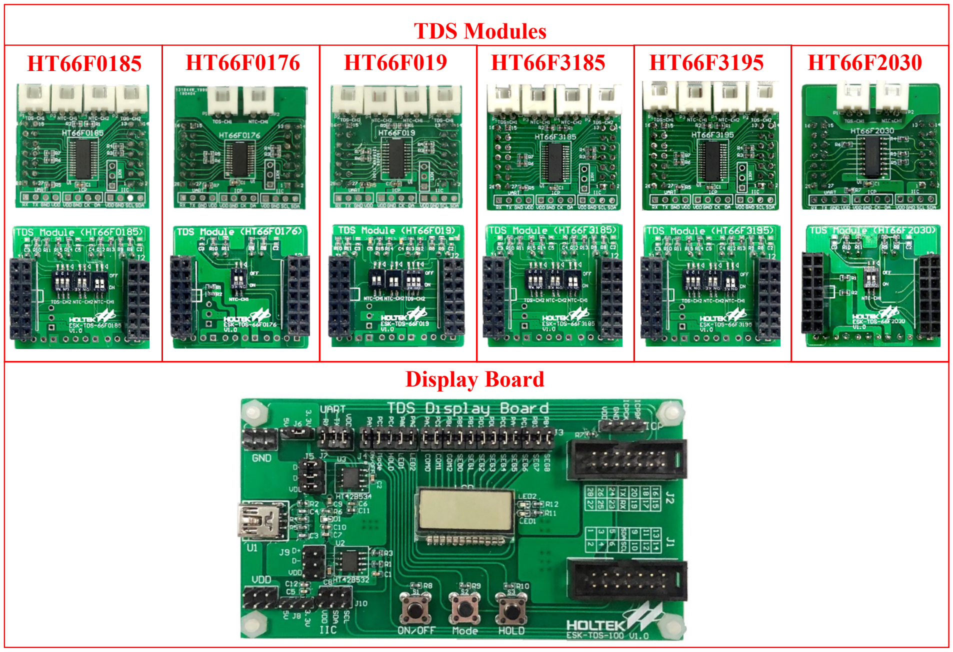
(3) Byte6~7 indicates the standard solution concentration value sent from the host to the slave, which is 10 times the raw value. For example, if the actual concentration is 1000.0us/cm, then Byte6=0x27 and Byte7=0x10, with the high byte being first transmitted.

<table>
<tr><th colspan="2">TDS Water Quality Detection Module Communication Protocol</th></tr>
<tr><td>Host Commands</td><td>
(4) After receiving the command from the host, the slave will first return an acknowledgement indicating that it has received the command and is calibrating. The host can obtain the calibration information at regular intervals until the calibration is completed.
5. Host sets the module to enter NTC calibration mode (Command:0x04)
<table>
<tr><td>Byte1</td><td>Byte2</td><td>Byte3</td><td>Byte4~7</td><td>Byte8</td></tr>
<tr><td>Frame Header</td><td>Length</td><td>Command</td><td>Data</td><td>Checksum</td></tr>
<tr><td>0x55</td><td>0x07</td><td>0x04</td><td>…</td><td>…</td></tr>
</table>
Note:
(1) Byte4 indicates the NTC channel. Byte4=0x01 means to set the NTC channel 1 to enter the calibration mode.
(2) Byte5~6 indicates the calibration solution temperature sent from the host to the slave, whose value is 10 times the raw value. For example, if Byte5=0x01 and Byte6=0x01, then the solution temperature is 25.7°C.
(3) After receiving the command from the host, the slave will first return an acknowledgement indicating that it has received the command and is calibrating. The host can obtain the calibration information at regular intervals until the calibration is completed.
6. Host obtains conductivity and temperature values (Command:0x05)
<table>
<tr><td>Byte1</td><td>Byte2</td><td>Byte3</td><td>Byte4~7</td><td>Byte8</td></tr>
<tr><td>Frame Header</td><td>Length</td><td>Command</td><td>Data</td><td>Checksum</td></tr>
<tr><td>0x55</td><td>0x07</td><td>0x05</td><td>…</td><td>…</td></tr>
</table>
Note:
(1) Byte4 indicates the channel. Byte4=0x01 means to obtain the conductivity and temperature values of channel 1.
(2) The conductivity unit is us/cm and the temperature unit is °C. The obtained conductivity and temperature values both are 10 times the raw values.
7. Host requires the module to enter sleep mode (Command:0x06)
<table>
<tr><td>Byte1</td><td>Byte2</td><td>Byte3</td><td>Byte4~7</td><td>Byte8</td></tr>
<tr><td>Frame Header</td><td>Length</td><td>Command</td><td>Data</td><td>Checksum</td></tr>
<tr><td>0x55</td><td>0x07</td><td>0x06</td><td>0x00</td><td>0x62</td></tr>
</table>
Note: After receiving the command from the host, the slave will directly enter the sleep mode without returning an acknowledgement.
</td></tr>
<tr><td>Slave Commands</td><td>
1. Slave sends product information to host (Command:0x80)
<table>
<tr><td>Byte1</td><td>Byte2</td><td>Byte3</td><td>Byte4~10</td><td>Byte11</td></tr>
<tr><td>Frame Header</td><td>Length</td><td>Command</td><td>Data</td><td>Checksum</td></tr>
<tr><td>0x55</td><td>0x0a</td><td>0x80</td><td>…</td><td>…</td></tr>
</table>
Note:
(1) Byte4 indicates the channel 1 probe type. Byte4=0x00 means the channel has no TDS, Byte4=37/57/67 indicates the corresponding probe type.
(2) Byte5 indicates the channel 2 probe type. Byte5=0x00 means the channel has no TDS, Byte5=37/57/67 indicates the corresponding probe type.
(3) Byte6 indicates the NTC channel count.
2. Slave sends TDS calibration information to host (Command:0x81)
<table>
<tr><td>Byte1</td><td>Byte2</td><td>Byte3</td><td>Byte4~10</td><td>Byte11</td></tr>
<tr><td>Frame Header</td><td>Length</td><td>Command</td><td>Data</td><td>Checksum</td></tr>
<tr><td>0x55</td><td>0x0a</td><td>0x81</td><td>…</td><td>…</td></tr>
</table>
Note:
(1) Byte4=0x00 means the TDS is not calibrated; Byte4=0x01 means the TDS is calibrated.
(2) Byte5 indicates the channel. Byte5=0x01 means to send the TDS calibration information of channel 1.
(3) Byte6 indicates the calibration mode and calibration points. Bit7 indicates the calibration mode; bit7=0 means single-point mode, bit7=1 means multi-point mode. Bit6~bit0 indicate the current TDS calibration point.
(4) Byte7~8 indicates the calibration standard concentration (unit: us/cm), whose value is 10 times the actual value. The high byte is transmitted first then the low byte.
</td></tr>
</table>

<table>
<tr><th colspan="2">TDS Water Quality Detection Module Communication Protocol</th></tr>
<tr><td>Slave Commands</td><td>
(5) Byte9~10 indicates the solution temperature (unit: °C) when calibrating TDS, whose value is 10 times the actual value. For example, if Byte7=0x01 and Byte8=0x01, then the solution temperature is 25.7°C.
3. Slave sends NTC calibration information to host (Command:0x82)
<table>
<tr><td>Byte1</td><td>Byte2</td><td>Byte3</td><td>Byte4~10</td><td>Byte11</td></tr>
<tr><td>Frame Header</td><td>Length</td><td>Command</td><td>Data</td><td>Checksum</td></tr>
<tr><td>0x55</td><td>0x0a</td><td>0x82</td><td>…</td><td>…</td></tr>
</table>
Note:
(1) Byte4=0x00 means the NTC is not calibrated; Byte4=0x01 means the NTC is calibrated.
(2) Byte5 indicates the channel. Byte5=0x01 means to send the NTC calibration information of channel 1.
(3) Byte6~7 indicates the calibration solution temperature (unit: °C), whose value is 10 times the actual value. For example, if Byte7=0x00 and Byte8=0xfa, then the calibration solution temperature is 25.0°C.
4. Slave returns acknowledgement signal (Command:0x83/0x84)
<table>
<tr><td>Byte1</td><td>Byte2</td><td>Byte3</td><td>Byte4~10</td><td>Byte11</td></tr>
<tr><td>Frame Header</td><td>Length</td><td>Command</td><td>Data</td><td>Checksum</td></tr>
<tr><td>0x55</td><td>0x0a</td><td>0x83/0x84</td><td>…</td><td>…</td></tr>
</table>
Note: When the slave receives the host's command that requires it to enter the TDS/NTC calibration mode, the slave will return an acknowledgement signal to the host.
5. Slave returns conductivity and temperature values (Command:0x85)
<table>
<tr><td>Byte1</td><td>Byte2</td><td>Byte3</td><td>Byte4~10</td><td>Byte11</td></tr>
<tr><td>Frame Header</td><td>Length</td><td>Command</td><td>Data</td><td>Checksum</td></tr>
<tr><td>0x55</td><td>0x0a</td><td>0x85</td><td>…</td><td>…</td></tr>
</table>
Note:
(1) Byte4 indicates the channel. Byte4=0x01 means to send the conductivity and temperature values of channel 1.
(2) Byte5~6 indicates the conductivity (unit: us/cm). The high byte is transmitted first then the low byte. The transmitted value is 10 times the actual conductivity value.
(3) Byte7~8 indicates the temperature (unit: °C), whose value is 10 times the actual temperature value.
</td></tr>
</table>

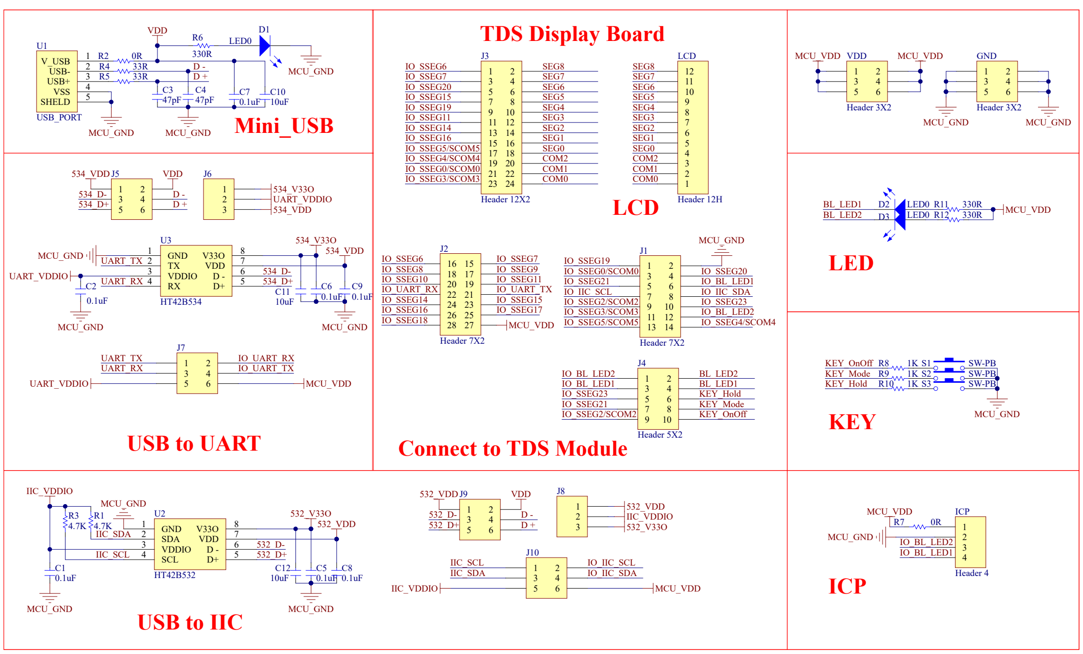
7 Appendix

7.1 Physical Pictures

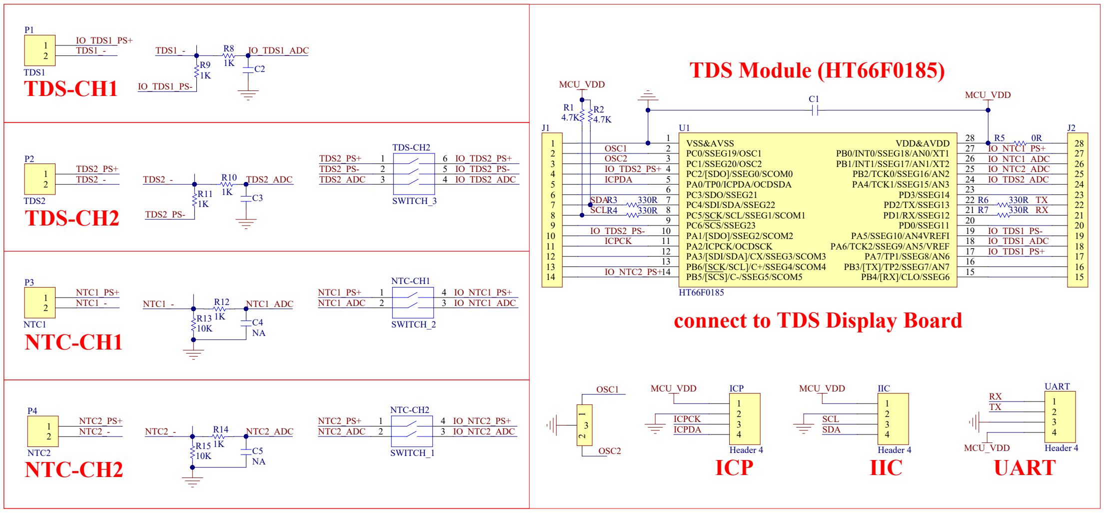


7.2 Development Board Schematics

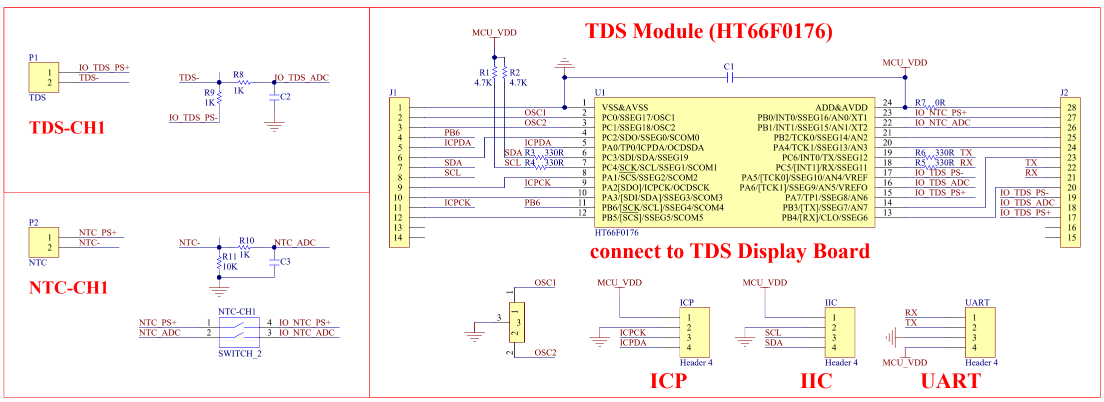
TDS Display Board



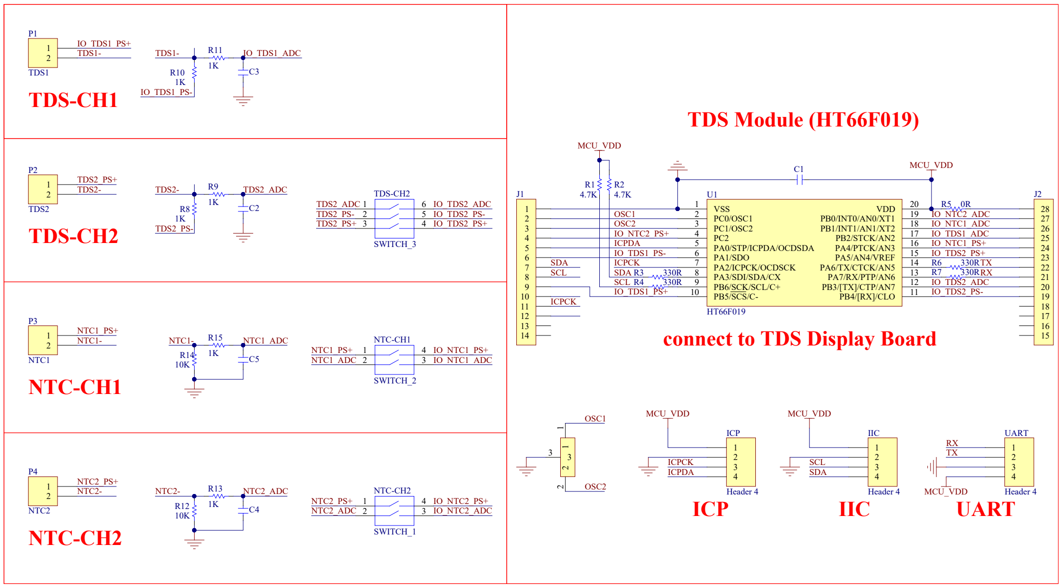
HT66F0185 TDS Module



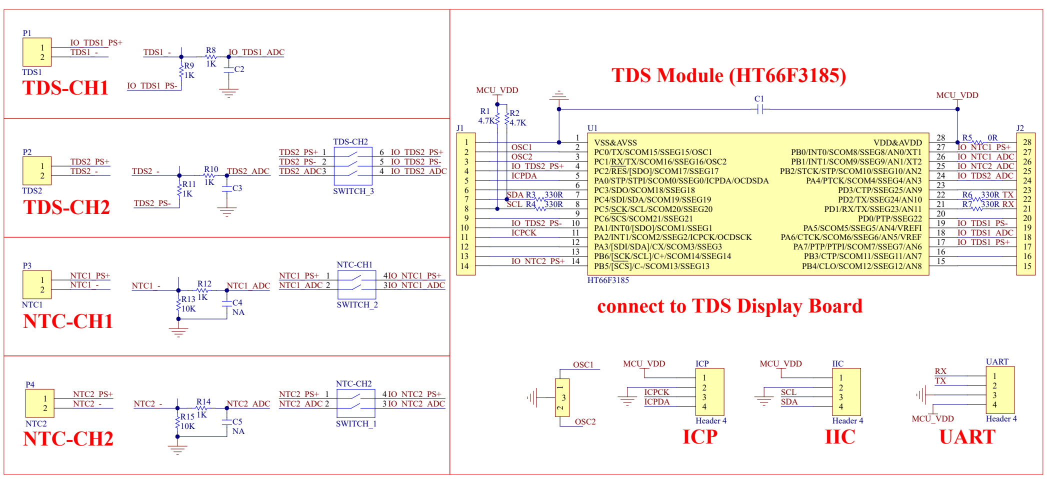
HT66F0176 TDS Module



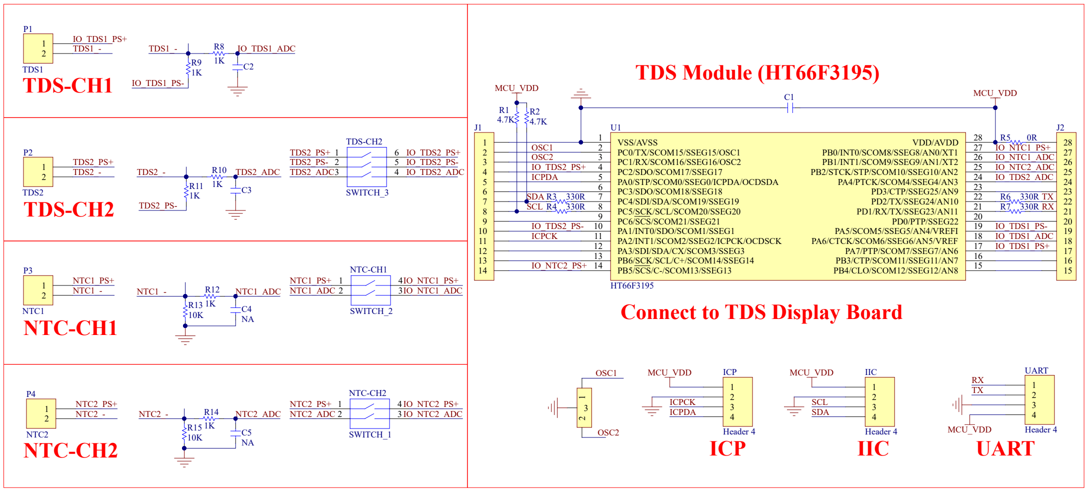
HT66F019 TDS Module



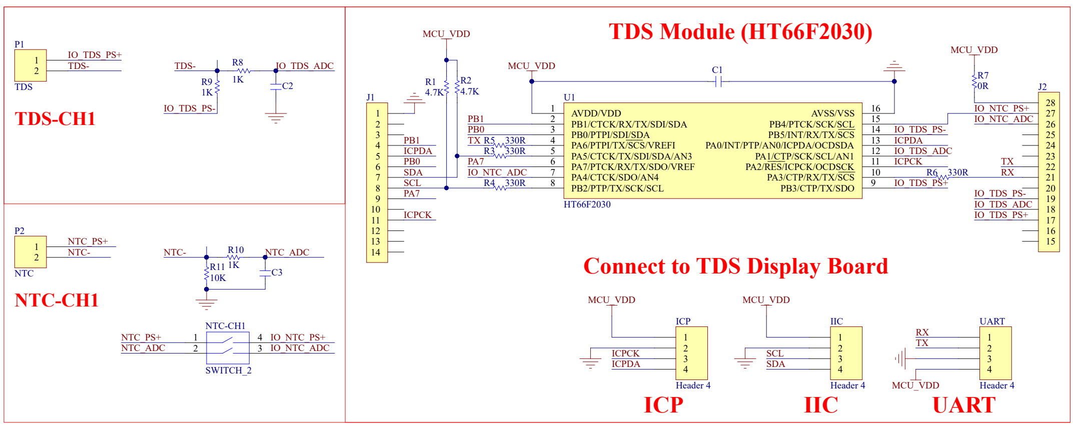
HT66F3185 TDS Module



HT66F3195 TDS Module



HT66F2030 TDS Module

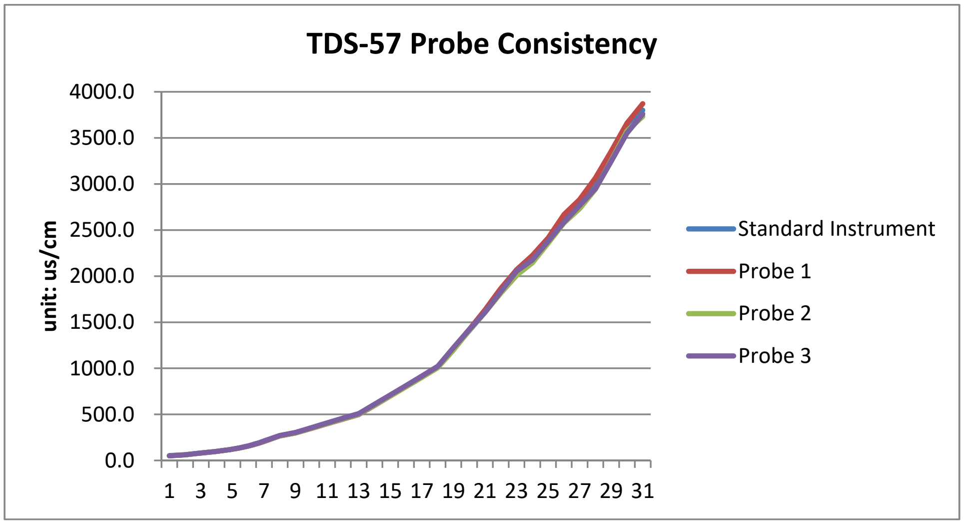


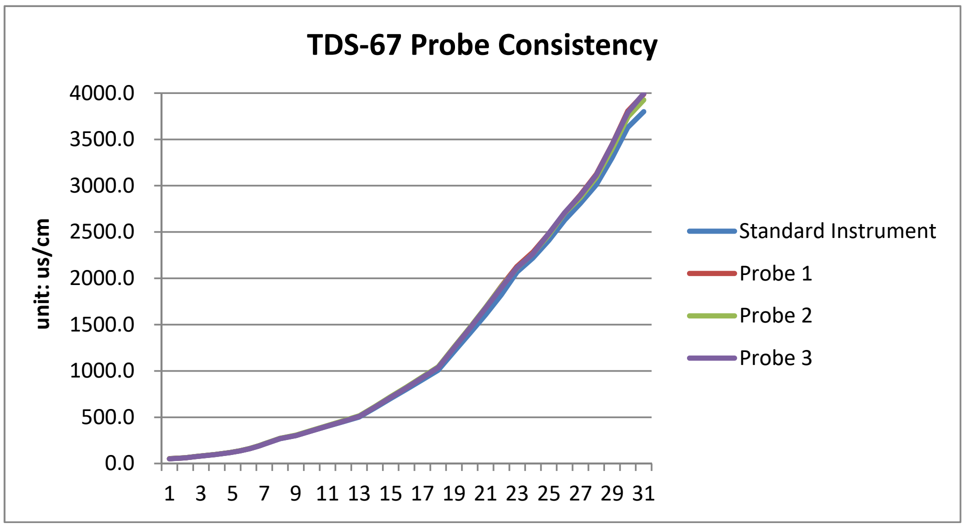
7.3 Tests

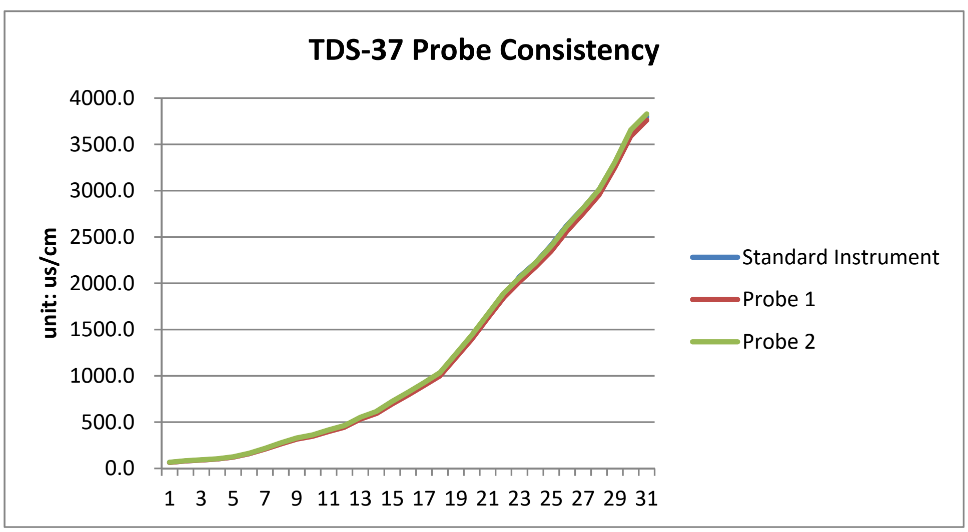
V_{DD}=5.0V; HIRC=8MHz; Probe Type: TDS-57										
Standard Instrument		Probe 1		Probe 2		Probe 3		Probe 1	Probe 2	Probe 3
NTC(°C)	TDS (µs/cm)	NTC(°C)	TDS (µs/cm)	NTC(°C)	TDS (µs/cm)	NTC(°C)	TDS (µs/cm)	Relative Error compared with Standard Instrument (%)		
25.3	52.0	25.4	50.3	25.4	50.5	25.4	50.3	-3.27	-2.88	-3.27
25.3	61.6	25.3	61.0	25.3	61.7	25.2	61.3	-0.97	0.16	-0.49
25.4	80.8	25.5	79.0	25.5	80.5	25.4	80.0	-2.23	-0.37	-0.99
25.4	101.5	25.4	100.3	25.4	101.0	25.4	101.0	-1.18	-0.49	-0.49
25.4	121.0	25.4	119.2	25.4	120.4	25.4	120.6	-1.49	-0.50	-0.33
25.4	158.8	25.3	157.5	25.3	158.8	25.3	159.6	-0.82	0.00	0.50
25.4	211.0	25.3	207.0	25.3	208.6	25.4	210.7	-1.90	-1.14	-0.14
25.4	269.0	25.3	265.4	25.3	267.6	25.3	270.6	-1.34	-0.52	0.59
25.5	302.0	25.4	297.4	25.4	299.9	25.4	304.1	-1.52	-0.70	0.70
25.4	353.0	25.3	348.4	25.3	351.5	25.4	355.9	-1.30	-0.42	0.82
25.3	403.0	25.2	397.7	25.2	400.6	25.2	407.5	-1.32	-0.60	1.12
25.4	453.0	25.3	448.2	25.3	451.8	25.3	458.9	-1.06	-0.26	1.30
25.5	502.0	25.3	497.8	25.4	500.3	25.4	507.9	-0.84	-0.34	1.18
25.5	601.0	25.5	596.7	25.5	599.7	25.5	609.8	-0.72	-0.22	1.46
25.4	702.0	25.3	698.7	25.3	700.0	25.3	710.4	-0.47	-0.28	1.20
25.4	802.0	25.4	801.1	25.4	801.1	25.4	813.0	-0.11	-0.11	1.37
25.5	904.0	25.4	905.2	25.4	901.6	25.4	915.1	0.13	-0.27	1.23
25.6	1008.0	25.5	1011.3	25.5	1007.3	25.5	1020.5	0.33	-0.07	1.24
25.6	1209.0	25.5	1219.0	25.5	1197.5	25.5	1222.8	0.83	-0.95	1.14
25.7	1406.0	25.6	1419.7	25.6	1408.8	25.6	1418.1	0.97	0.20	0.86
25.6	1608.0	25.6	1634.2	25.6	1608.1	25.6	1608.1	1.63	0.01	0.01
25.7	1821.0	25.9	1864.8	25.9	1813.3	25.8	1830.2	2.41	-0.42	0.51
25.5	2070.0	25.5	2067.3	25.5	2007.7	25.5	2054.0	-0.13	-3.01	-0.77
25.5	2220.0	25.5	2223.8	25.5	2143.4	25.5	2174.5	0.17	-3.45	-2.05
25.4	2410.0	25.4	2413.9	25.4	2358.1	25.3	2379.1	0.16	-2.15	-1.28
25.5	2630.0	25.4	2667.1	25.4	2575.8	25.4	2583.3	1.41	-2.06	-1.78
25.4	2810.0	25.3	2832.4	25.3	2732.3	25.3	2769.1	0.80	-2.77	-1.46
25.3	3010.0	25.3	3065.9	25.3	2943.1	25.3	2947.8	1.86	-2.22	-2.07
25.3	3300.0	25.2	3355.8	25.2	3256.6	25.2	3245.9	1.69	-1.32	-1.64
25.3	3630.0	25.2	3659.3	25.2	3576.1	25.2	3551.1	0.81	-1.48	-2.17
25.3	3800.0	25.3	3870.7	25.2	3731.6	25.2	3759.4	1.86	-1.80	-1.07

V_{DD}=5.0V; HIRC=8MHz; Probe Type: TDS-67										
Standard Instrument		Probe 1		Probe 2		Probe 3		Probe 1	Probe 2	Probe 3
NTC(°C)	TDS (μs/cm)	NTC(°C)	TDS (μs/cm)	NTC(°C)	TDS (μs/cm)	NTC(°C)	TDS (μs/cm)	Relative Error compared with Standard Instrument (%)		
25.3	52.0	25.6	51.3	25.7	51.7	25.6	51.1	-1.35	-0.58	-1.73
25.3	61.6	25.6	61.5	25.6	62.0	25.6	61.0	-0.16	0.65	-0.97
25.4	80.8	25.7	80.8	25.8	81.4	25.8	80.0	0.00	0.74	-0.99
25.4	101.5	25.7	101.3	25.8	102.2	25.7	100.6	-0.20	0.69	-0.89
25.4	121.0	25.7	121.4	25.8	122.2	25.7	120.4	0.33	0.99	-0.50
25.4	158.8	25.6	159.8	25.7	161.0	25.7	158.5	0.63	1.39	-0.19
25.4	211.0	25.7	211.1	25.8	212.7	25.7	209.7	0.05	0.81	-0.62
25.4	269.0	25.6	270.0	25.7	272.1	25.6	268.7	0.37	1.15	-0.11
25.5	302.0	25.7	304.4	25.8	306.6	25.7	302.3	0.79	1.52	0.10
25.4	353.0	25.7	355.3	25.8	358.1	25.8	353.1	0.65	1.44	0.03
25.3	403.0	25.6	407.5	25.7	410.5	25.7	405.4	1.12	1.86	0.60
25.4	453.0	25.6	458.2	25.7	461.5	25.6	455.9	1.15	1.88	0.64
25.5	502.0	25.7	510.3	25.8	514.3	25.8	507.7	1.65	2.45	1.14
25.5	601.0	25.7	613.1	25.8	616.7	25.8	609.5	2.01	2.61	1.41
25.4	702.0	25.6	717.6	25.7	721.8	25.7	714.1	2.22	2.82	1.72
25.4	802.0	25.6	823.3	25.7	825.7	25.7	817.6	2.66	2.96	1.95
25.5	904.0	25.7	931.1	25.9	933.9	25.8	926.4	3.00	3.31	2.48
25.6	1008.0	25.8	1038.5	25.9	1042.9	25.8	1035.4	3.03	3.46	2.72
25.6	1209.0	25.8	1256.1	25.9	1257.6	25.9	1249.6	3.90	4.02	3.36
25.7	1406.0	25.8	1463.3	25.9	1468.7	25.9	1460.5	4.08	4.46	3.88
25.6	1608.0	25.8	1683.6	25.9	1684.3	25.8	1677.6	4.70	4.75	4.33
25.7	1821.0	26.0	1914.8	26.0	1910.0	26.0	1900.3	5.15	4.89	4.35
25.5	2070.0	25.8	2129.9	26.0	2113.1	25.9	2117.2	2.89	2.08	2.28
25.5	2220.0	25.7	2283.9	25.8	2266.8	25.7	2265.0	2.88	2.11	2.03
25.4	2410.0	25.6	2483.6	25.7	2468.1	25.7	2482.4	3.05	2.41	3.00
25.5	2630.0	25.7	2705.3	25.8	2704.1	25.7	2709.4	2.86	2.82	3.02
25.4	2810.0	25.6	2902.2	25.8	2872.6	25.7	2896.5	3.28	2.23	3.08
25.3	3010.0	25.5	3122.9	25.7	3090.1	25.6	3116.7	3.75	2.66	3.54
25.3	3300.0	25.5	3442.9	25.7	3393.3	25.6	3442.2	4.33	2.83	4.31
25.3	3630.0	25.5	3807.2	25.6	3742.8	25.6	3792.5	4.88	3.11	4.48
25.3	3800.0	25.5	3987.2	25.6	3925.4	25.6	3994.9	4.93	3.30	5.13

V_{DD}=5.0V; HIRC=8MHz; Probe Type: TDS-37							
Standard Instrument		**Probe 1**		**Probe 2**		**Probe 1**	**Probe 2**
NTC(°C)	**TDS (μs/cm)**	**NTC(°C)**	**TDS (μs/cm)**	**NTC(°C)**	**TDS (μs/cm)**	**Relative Error compared with Standard Instrument (%)**	
24.3	64.7	24.5	64.3	24.5	66.1	-0.62	2.16
24.1	81.0	24.4	80.3	24.4	82.7	-0.86	2.10
24.2	90.7	24.4	89.8	24.4	92.6	-0.99	2.09
24.1	101.5	24.3	100.8	24.3	104.0	-0.69	2.46
24.1	122.2	24.4	121.0	24.4	125.3	-0.98	2.54
24.2	159.6	24.4	158.4	24.4	164.0	-0.75	2.76
24.1	212.0	24.4	208.8	24.4	216.7	-1.51	2.22
24.2	269.0	24.4	264.8	24.4	275.4	-1.56	2.38
24.2	321.0	24.4	316.2	24.4	329.0	-1.50	2.49
24.2	353.0	24.4	347.5	24.4	361.8	-1.56	2.49
24.2	404.0	24.4	398.7	24.4	414.4	-1.31	2.57
24.2	453.0	24.4	445.7	24.4	463.2	-1.61	2.25
24.1	540.0	24.4	531.5	24.4	552.8	-1.57	2.37
24.1	601.0	24.3	592.0	24.4	614.6	-1.50	2.26
24.1	708.0	24.4	697.0	24.4	724.7	-1.55	2.36
24.1	802.0	24.3	792.2	24.3	823.1	-1.22	2.63
24.0	906.0	24.2	894.7	24.3	926.0	-1.25	2.21
24.0	1010.0	24.2	999.6	24.2	1035.2	-1.03	2.50
24.0	1209.0	24.2	1197.0	24.2	1235.9	-0.99	2.22
24.0	1410.0	24.2	1395.4	24.2	1439.7	-1.04	2.11
24.1	1628.0	24.2	1624.0	24.2	1665.6	-0.25	2.31
24.1	1844.0	24.2	1844.5	24.2	1891.3	0.03	2.57
24.0	2070.0	24.2	2017.2	24.3	2061.2	-2.55	-0.43
24.0	2220.0	24.2	2175.3	24.3	2218.8	-2.01	-0.05
24.0	2410.0	24.3	2347.5	24.3	2401.6	-2.59	-0.35
24.1	2630.0	24.3	2564.8	24.3	2623.0	-2.48	-0.27
24.1	2810.0	24.3	2753.8	24.3	2810.6	-2.00	0.02
24.1	3010.0	24.3	2952.2	24.3	3011.1	-1.92	0.04
24.2	3300.0	24.3	3251.2	24.4	3307.9	-1.48	0.24
24.1	3630.0	24.4	3589.1	24.4	3657.6	-1.13	0.76
24.1	3800.0	24.4	3761.4	24.4	3828.7	-1.02	0.76


TDS-57 Probe Consistency
unit: us/cm
4000.0
3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
Standard Instrument
Probe 1
Probe 2
Probe 3


TDS-67 Probe Consistency
unit: us/cm
4000.0
3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
Standard Instrument
Probe 1
Probe 2
Probe 3


TDS-37 Probe Consistency
unit: us/cm
4000.0
3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
Standard Instrument
Probe 1
Probe 2